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A CIRCUIT FOR RECORDING MULTIPLY-COINCIDENT DISCHARGES OF GEIGER-MUELLER COUNTERS.

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Since the cosmic rays, as we detect and measure them, are ionizing corpuscular rays, capable of penetrating considerable thickness of matter, they may be recorded by counting the coincident discharges of two or more Geiger-Mueller counters, placed in line. Inherently, this method of measuring cosmic rays has the following advantages: (1) It is insensitive to radioactive rays. (2) It is essentially independent of temperature, vibrations, etc. (3) The radiation is measured without the interposition of much absorbing material. (4) It has directional selectivity. (5) It measures the number of rays and not their ionization and is, therefore, independent of variable transition effects. (6) The apparatus is rugged, easily transported, and has no delicate parts. (7) It is inexpensive and easily assembled. The method suffers from the disadvantage that a long time is required for a measurement.

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Several circuits have been proposed and used. The principle names in this connection are Bothe,[1] Tuve,[2] Rossi [3] and Mott-Smith.[4] The circuit which we have developed departs somewhat from all of these in details but not in essentials, and it has advantages both as regards sensitivity and the elimination of false coincidences. Furthermore, it is self-contained and easily transported for field work.

The assembled apparatus is shown in Figs. 1, 2, 3, and 4 and the circuit diagram in Fig. 5. Each of the three counters (Fig. 5*a*) is connected to the grid of a tetrode, the negative pulse cutting off the plate current. The positive output pulse is inverted in a second tetrode stage and applied as a negative pulse to the grid of the third stage three-element low-μ tube. The duration of the pulse is reduced through the rapid recovery time of this grid to about 2.5×10^{-5} seconds. Two or more such circuits are coupled together (Fig. 5*b*) by joining the plates of the third stages in parallel through a .2 megohm resistance in a manner somewhat similar to the coincidence selection method used by Rossi.[3] The grid of the next tube is negatively biased to such an extent as to pass only simultaneous pulses from all of the counters. Such pulses, only 2×10^{-5} seconds long, are prolongated on the succeeding grid, by a system of capacity and resistance, to .012 second, so that they will operate a recording device. This prolonged pulse is of reduced amplitude and is negative. Therefore, the next stage is required for inversion and amplification before the pulse is applied to the final output stage.

All voltages are supplied from a 110 a.c. primary power supply according to methods standard for a.c. radio receivers. The tubes are those most commonly used in such receivers and are the best developed and the least expensive. 1500 volts is supplied to the counters from rectified a.c., controlled to within a volt or two by the special tetrode control circuit [5] which we have described in this JOURNAL, and which we unhesitatingly recommend for use with counters. The coinci-

[1] W. Bothe, *Zs. f. Phys.*, **59**, 1, 1929.

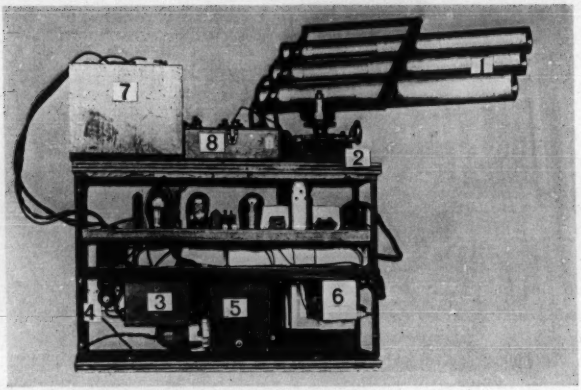
[2] M. A. Tuve, *Phys. Rev.*, **35**, 651, 1930.

[3] B. Rossi, *Nature*, **125**, 636, 1930.

[4] L. M. Mott-Smith, *Phys. Rev.*, **39**, 403, 1932.

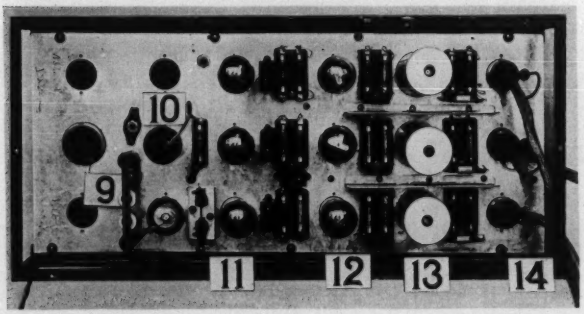
[5] J. C. Street and Thomas H. Johnson, JOUR. OF THE FRANK. INST., **214**, 155, 1932.

FIG. 1.



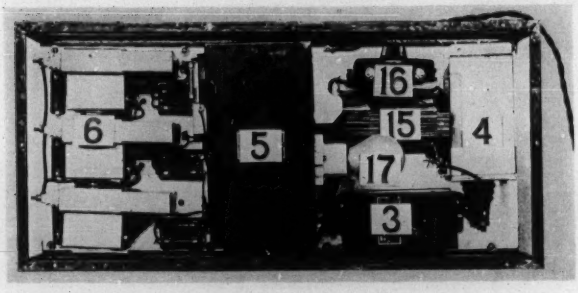
Complete assembly of the Circuits. 1. Aluminum tubes containing the counters and the first amplifying stage. Inside assembly shown in Fig. 4. 2. Watch Recorder. 3. High Potential transformer. 4. 1 mfd. 2000 volt condenser for counter potential. 5. B-eliminator. 6. Filter condensers and 2d stage grid bias batteries. 7. Grid batteries. 8. Milliammeter for reading counter potential.

FIG. 2.



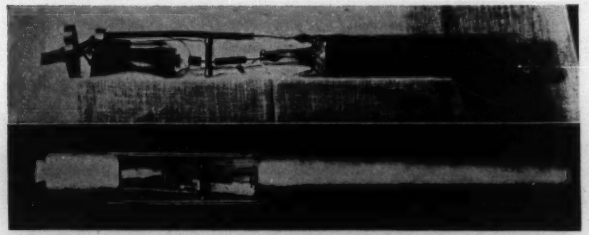
Upper Panel. 9. Voltage-control fixed resistors (right). Voltage-control variable grid resistors (above). Grid battery jack (below). 10. Meter jack (left) for counter potential. Kenetron tube (below) for rectifying counter potential. 11. Three stages of the adding circuit. 12. Third stages of the three amplifier circuits. 13. Second stages of the three amplifier circuits. 14. Cable jacks to the first stages of the amplifier circuits (contained in the aluminum tubes).

FIG. 3.



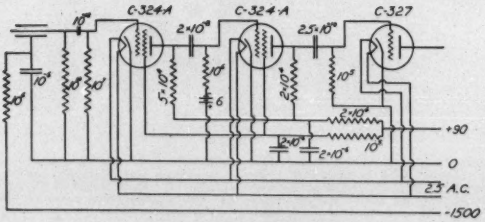
Lower Panel. 15. Filament transformers. 16. Variable resistor in primary of the high potential transformer. 17. Fixed resistor in primary of the high potential transformer.

FIG. 4.

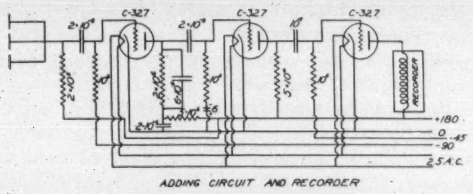


Counter tube assembly.

FIG. 5.



(*a*) Counter and amplifying circuit.



ADDING CIRCUIT AND RECORDER

(*b*) Adding and recording circuit.

Circuit diagram and constants for the coincidence recording circuit. (*a*) is one of the three similar amplifying circuits connected in parallel as shown at the left of *b*. Capacities are given in farads, resistances in ohms, and potentials in volts.

dences are recorded on a counting instrument consisting of a Western Electric telephone relay which operates the escapement arm of an Ingersoll watch. This instrument is capable of recording 60 evenly spaced pulses per second.

The elimination of false coincidences is associated with the resolving time, τ, of the circuits as well as with the avoidance of what we may call "pick up." The resolving time in this circuit depends upon the capacity and the resistance of the third stage grid and therefore it may be made as short as the initial breakdown pulse in the counter. With a capacity of .00025 microfarad and a .1 megohm resistance, the 2/3 relaxation time is 2.5×10^{-5} seconds. Theoretically the number of accidental counts for 2 counters is $2N^2\tau$. With $N = 100$ per min. and $\tau = 2.5 \times 10^{-5}$ secs., the number of accidental counts is 8×10^{-3} per minute, or one in two hours. With three counters it is $6N^3\tau^2$ or one in 700 days. This latter calculation, of course, refers to the case where all the double coincidences are the accidental ones. If this is not the case these figures require a simply computed modification. In putting the apparatus to the test it is necessary to realize the presence of groups of associated rays which produce real coincident discharges even though the counters are out of line and far apart. Because of these it is difficult to make an accurate test of the number of truly accidental counts but we believe we are realizing something very close to the theoretical number.

As regards accidental counts caused by pickup, our circuit has the advantage that the back pulse from the adding stage,

due to the discharge of other counters, is reduced to entirely negligible proportions through the two screen grid stages. Furthermore, the high voltage supply to each counter is protected from cross pulses by separate capacity-resistance filters. Each of the amplifying circuits is also supplied by individually filtered plate and screen grid potentials as is also the plate supply of the prolongation stage of the recording circuit.

The point of greatest difference between this circuit and others which have been used is the three stages of amplification before the pulses are combined. These three amplifying stages have the advantage that low amplitude pulses from the counters are increased to be as effective as the strongest and there are practically no variations in the amplitudes of the pulses impressed upon the adding circuit, each representing complete cut off of the plate current in the third stage. This advantage is further augmented by the characteristics of the adding circuit itself, for it has a better-than-linear adding advantage. The meaning of this statement can be made clear by an example. With three low-μ tubes connected in parallel, a pulse on one of them produces an 18 volt pulse on the adding circuit. Simultaneous pulses on two of them produce 42 volt pulses and pulses on all three produce a 168 volt pulse on the adding circuit or four times the pulse produced by a double discharge. It is easy, therefore, to adjust the bias on the grid of the tube which receives this pulse to separate the weakest triples from the strongest doubles.

The sensitivity of a counter depends, principally, upon the potential applied to it. The higher this can be raised above the starting potential, without producing continuous discharges, or unduly high individual counting rates, the more sensitive is the counter; that is, the more likely it is to discharge when an ion is formed in it. The extent of possible over-voltage is greater, the higher the resistance connecting the counter wire to ground. With a 10^{10} ohm resistance the potential can be raised hundreds of volts above the threshold and there is good evidence to believe that under these conditions the counters are very nearly 100 per cent. efficient.

The finite recovery time, σ, however, places a limit on the efficiency which also depends upon the individual counting

rates N. On this consideration $(1 - N\sigma)$ is the efficiency of a single counter and $(1 - N\sigma)^3$ that of three counters recording coincidences. As an example, if σ is .003 second, the efficiency for triples is 97 per cent. with a counting rate of 200 per minute. In order to realize a 2/3 recovery time as short as .003 second with a 10^{10} ohm resistance the capacity of the central wire system must be of the order of .3 cms, but with high over-voltage, and three amplifying stages full recovery is by no means required for complete cut off in the third stage and the effective recovery time can be of the order of 1/1000 seconds even though the capacity of the counter wire is 2 or 3 centimeters. It is advisable, however, to reduce the capacity of the central system to its lowest possible value and to adjust the grounding resistance to as high a value as is consistent with an efficient recovery time. This can be tested by measuring the effect on the coincident counting rate due to cosmic rays of an increased individual counting rate controlled by the proximity of radioactive material.

Although it would appear at first that the recovery time is prolonged through the use of a high resistance, the higher possible over-voltage is a compensating factor, since only a small fraction of the total recovery may be required to sensitize the counters. Discharges which take place prior to full recovery are of course weaker, but the amplification in the three stages is such that most of these pulses are raised to full strength before they are combined. The pulses on the grid of the first stage depend not only upon the extent of recovery of the counter but also upon the mutual counter wire-grid capacity. For the most efficient arrangement this should be made as large as possible without unduly increasing the total counter wire capacity. The most efficient capacity of the coupling condenser is about that of the counter wire itself and can be determined experimentally by adjusting it to the value which gives the highest counting rate in the presence of a strong source of gamma rays, the latter being placed at the distance for maximum counting rate. Undoubtedly the insensitive time following a discharge is not fully explained by such simple considerations as those given above. In fact there are indications that the duration of the discharge itself is an important consideration, but this, also, seems to depend

upon the capacity of the counter wire in such a way as to lend additional support to the advisability of reducing it as far as possible.

In the making of the counters themselves, we have followed the technique outlined by Mott-Smith [4] in that the counter tube is first baked in the manner customary for degasing a high vacuum tube. It is then filled with air to the appropriate pressure, depending upon cylinder and wire diameters and the desired operating potential.

The probability of good operation is increased, and the residual counting rate is lowered and is made less dependent upon the extent of over-voltage if a small amount of iodine vapor [6] is introduced with the air. For this purpose in filling the counters the air is merely allowed to pass over some iodine crystals at a temperature only slightly above that of the room. Successful counters have been made with cylinders of copper, nickel and silver, and with wires of 3 mil tungsten. To prevent surface breakdown over the outside of the counter due to adsorbed moisture, we have boiled the tube in hot paraffin.

Dr. E. C. Stevenson participated in the latter stages of this development. We also acknowledge the technical aid of Mr. J. H. Fergus and Mr. Lewis Fussel. Mr. Austin G. Nester has been of very efficient service in making the counters.

[6] The effect of the iodine is probably to react with any free photoelectrically active material in the counter. We are indebted to Dr. G. L. Locher for the suggestion of using it.

WHAT THE MACHINE IS DOING TO MANKIND.*

BY

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Economist for Commonwealth and Southern Corporation of New York.

Mr. Chairman, Ladies and Gentlemen:

I am not unmindful of the great honor you confer upon me by this invitation to address this very distinguished society, The Franklin Institute.

We live in an atmosphere today particularly conducive to critics. We seem to have plenty of the stuff of which they are born. Verily, our achievements of liberty are great. We think as we please. The mass-man has been released and is going places. He and his self-appointed spokesmen are attacking everything, the machine and industrialism included.

Well, this attacking business is a pleasant and exhilarating exercise. For while we attack, we have no need of doubt and less for constructive planning. We only need to affirm vehemently that whatever is, is wrong. The spell of indignation is upon us. We unconsciously become the high priests of evangelism and change. Change of what sort? It is no matter. Any sort, just so it is change. "Tear down and you will build something better" is the favorite axiom of critical philosophers, though by now Greece and Rome have good reason for doubting its truth. It is to be observed, however, that the philosopher always leaves the work of reconstruction to more practical people.

In the wake of this criticism generally, the machine and industrialism have been caught up in a perfect barrage of disparaging pronouncements, and for the moment both seem to be faring badly. The criticism may be more marked in my section of the country, The Deep South, because our cultural pattern has been determined largely by an almost exclusive agricultural technique only yesterday emerged from the

* Presented at the Stated Meeting held Wednesday, November 16, 1932.

slavery type so persistent in exclusively agricultural countries. This explains more of the tenant system, incidentally, than some of us are willing to admit.

For twenty years I have been an ardent advocate of the larger industrialization of the South. In this work it has become necessary from time to time to point out to an unbalanced population, 75 per cent. of which is rural, the benefits to be derived from industrialization. It is for this reason that I am now defending the machine and industrialism, the beneficial effects of which are being seriously questioned by many in my section of the country.

Nor is this criticism peculiar to the South. It is world wide. The intelligentsia of the most industrialized countries of the world are merciless in their criticisms of the machine.

Fundamentally, here is the reason for much of the criticism of science and the machine. We invent our machines, we use them, they work, we accept them. We inherit our institutions and metaphors and, therefore, must save them. Physically, we are neighbors. Psychologically, we are far apart. Our philosophical ideals are slow to change. The machine is not only indifferent to accepted philosophies, but impatient with them. It always wants to be getting on.

The philosophy of restless change so characteristic of Western Civilization was begot by science and nurtured into huskiness by the machine. The chief characteristic of Western Civilization has been its belief in science and the machine. It dares look facts in the face, and then do something about it.

On the other hand, the Oriental has attempted to solve his problems by metaphysical speculation with no recognition of the material forces which play about him and in his futile attempt to explain the universe thus, he has been driven to the philosophy of defeatism. There are evidences today that we of the West are getting tired and nothing is so tragic as a tired, discouraged, decaying culture.

The use of the machine has created many problems for us. But hitherto, we have liked problems. Industry, which so widely uses science and the machine, must not neglect its social responsibility. Industry has created many of our religious, moral, political, and social problems. The machine

has changed our occupations, hours of labor, delights, recreations, social and religious ideals. Philosophers are being forced to take cognizance of these changes, and they are in none too good humor about it. Indeed, they are just now giving the machine fits. Things go on about our very heads without our knowing it. People and races are rarely conscious of the beginnings of their culture and more rarely conscious of its development.

There are two types of culture among all people—an idealistic culture about which everybody raves, and a materialistic culture about which nobody raves. Yet we all work at these two cultures, philosopher, sage, industrialist and laborer alike. The idealistic culture finds expression in religion, philosophy, and the fine arts. The materialistic culture is embodied in science, invention, machines, industry and commerce. Both types of culture blend to make the general cultural pattern a people enjoy and we all work together to produce that pattern. The materialistic culture has always enjoyed one distinctive function. It has been permitted to do the rather obviously prosaic thing of paying the bills for the idealistic culture, as any good taxpayer or philanthropically inclined individual can testify. It did this for Plato, and also for Aristotle, who had the good sense, by-the-way, to marry the richest woman in Athens. It did it for Dante and Shakespeare; and it continues to carry on somewhat handsomely by making possible colleges, universities, libraries, churches and a myriad host of other such institutional containers of our highly prized idealistic culture.

I guess it is a fact that idealistic culture has ever traveled on the back of materialistic culture. Business has never followed civilization, because there has been very little civilization without business. That first savage who had an urge for a trinket he did not own, and started bartering for it, started civilization. There is ample statistical evidence that the measure of a nation's idealistic culture is the ability of its industrial and commercial life to pay the bills and continue to carry on.

"In the sweat of thy face shalt thou eat bread." This classic phrase is not so much a curse as the statement of a principle. It is the principle that human life and cultural

progress is based upon energy. In the primitive, it is the energy of human muscle, "sweat of thy face." Later, domestic animals come into use and the burden is somewhat lightened. Animal power gives him some leisure and he begins to invent simple tools. A little later simple machines propelled by man-power, and later still this "sweat of thy face" power is supplemented by animals at the levers. Still later, steam, gas and electricity take the place of men and of animals at the levers, and a man is gradually liberated from arduous toil. He may now begin intelligently tending instead of muscularly driving the machine.

As we know the machine, it is the essence of practicality applied directly to our agricultural, industrial, commercial and home life, for the purpose of changing our environment, directly; and changing our political, social and cultural life, indirectly.

The machine is the very basis of our modern economic world. And while it is not all good, it is by no means all bad. Making a free use of the machine, the United States has experienced the most marvelous century and a half in the history of mankind. From 1779 to 1929, we increased our national income from $400,000,000 to over $80,000,000,000, our national wealth from approximately $500,000,000 to something like $375,000,000,000. The population in the meantime had grown from 3,000,000 to 120,000,000. Since 1900, the life of a generation, our families have increased from 16,000,000 to 25,000,000. We have housed 15,000,000 in new homes, wired 20,000,000 homes for electricity, installed 20,000,000 telephones, and have 40,000,000 people, more or less, listening to 12,000,000 radios. That much of the stuff they hear is not worth listening to is no matter now. It will improve.

Our progress has been remarked upon by philosopher and sage, common man and carping critic, at home and abroad. There will be more yet to remark. For despite the distressing present, we shall see a yet more glorious future. The possibilities of our cultural development are limited only by our economic development, and our economic development is limited only by the wants of men and these are boundless, for there is no such thing as a "wantless civilization."

Critics of the machine and our industrialism will say that this is merely materialistic progress and may mean nothing in the cultural life of the nation. But that is exactly what it does mean. It has created the wealth and provided the leisure for our cultural advance. These critics should remember that idealistic cultures always flourish in those periods when people have made the greatest materialistic advance. There is good evidence for believing that the various "Golden Ages" in fine arts were not so much the result of literary revolts as the revolts of the well-to-do against the dead, dry, traditional cultures born of poverty and incrusted in form and ceremonial. At any rate, it is significant that the Periclean Age in Grecian history came exactly at the time when Athens was trading with a thousand posts in the Mediteranean basin and that when she lost this commerce, her culture went out the window. The Golden Age of Roman Literature followed close on the heels of Rome's greatest commercial expanse. The Italian Renaissance was bought and paid for by business men who discovered the art of converting raw materials into finished products and shipping them out to the peoples of the world. Profits are as essential in a cultural expanse as the geniuses. At any rate, the geniuses have always arrived just behind the profits.

But more specifically, no century and a half in historical time has made the cultural advance Western Civilization has made since 1800. In the United States, for instance, we have provided higher standards of living, unequaled political rights and privileges, a degree of social equality, a diffusion of opportunity, a scope of educational advantages, an amount of religious freedom and economic independence unprecedented in the history of the world. No nation has now, or ever has had, so many of its children in schools and colleges. In the life of one generation we have seen a 12-hour working day go and tagged inhuman, high school attendance increase 700 per cent., college attendance increase 300 per cent., and through libraries, the press, extension courses and radio educational opportunities literally hurled at the heads of all. If it does not stick, it is not the fault of the machine, which has so largely contributed to the program by creating the wealth with which to pay for it all. Only blockheads need longer

remain ignorant in this country. Since 1900, our savings in banks, building and loan associations increased six times, we multiplied our life insurance over 1200 per cent., and while this hard-boiled stuff was going on, our charity and philanthropy for idealistic cultural purposes rose to our tenth ranking industry!

We need not claim that the machine was the creator of this idealistic cultural program. It is enough for it to say that it created the wealth and provided the leisure that the thing might happen. For wealth and leisure are essentials in any cultural advance.

Economic techniques have changed very slowly. In spite of the common error that we lived by agriculture *exclusively* prior to about 1800, it *was* the chief economic technique up to that time. Since then our adoption of the industrial technique has been rapid. While retaining sufficient of this basic industry of agriculture, the emphasis has been shifted somewhat and the fascinating achievement of American development in more recent years may be credited to production made possible by an improved agriculture and industry, both largely the result of the perfected machine.

In spite of such altruistic service, our intelligentsia are bringing harsh impeachments against the machine, and it is being thrust into outer darkness by honest, tender-hearted people who feel deeply.

Speaking at Leeds University in England recently, the Bishop of Ripon made a devastating onslaught on the poor old machine when he declared, "The enemy of progress now is not so much the beast within man as the machine which has him in its grip. The machine subjects the human spirit to a mental habit, a tyrannous technique, because men move in mechanical masses." It will be a great day for religion, not to mention the devil, when Bishops turn from preaching the beast out of men and devote their energies to converting iron and steel! The Rev. H. P. Frost recently exclaimed, "In this age of the machine, the shadow of a Frankenstein Monster falls like a sinister menace across the upward pathway of the race." He is more eloquent than the Bishop, but pitched in the same key. Professor Harry E. Barnes recently declared, "The machine has confused and will finally destroy its baffled

creator." Mr. Austin Freeman, a widely quoted author, believes that as the machine becomes more efficient man becomes less independent and self-reliant. He becomes more regimented, his personal liberty more abated, and his sensibilities become blunted and debased. This is pretty nearly saying that it takes more mental ingenuity to drive an ox-team than an automobile. It certainly takes a different vocabulary. And Sir Philip Gibbs has said that we shall either have to kill all the scientists or reform our morals. Well, some of our morals need reforming. They always have. But as bad as they are, I am in favor of giving our scientists one more chance. Professor Edward A. Ross in his "Outline of Sociology" says "the factory locksteps the worker," that the product of the machine is impersonal, and that "artists agree that machine production for the market is without the interest excited by hand production for an individual and that the products are neither *significant* nor *beautiful*."

If anything in this world has been glorified out of all reason, it is *handcrafts*. People who wax eloquent about the character of the worker and the beauty and personalization of the product of the handcraft days should reread their history to learn what handcraft workers put up with, and reexamine with critical eye the artistry of some of the products.

But, mind you, there is nothing new in all of this. Carlyle hated invention. Thackery despised the machine. Tennyson found new metaphors with which to damn the machine. Browning soundly disliked science and all of its doings while optimistically exclaiming, "God's in His Heaven, All's right with the world." Yet at that very moment his fellow men were naked and hungry in the streets for want of what the machine could have given them, and dying from simple contagions caused by the lack of simple sanitation which science could have supplied. Such is the idealism of poets and philosophers, however. They will have their whims. Goethe saw red every time he saw a cotton mill, but he enjoyed his fine clothes woven by the hands of peasants who toiled sixteen hours a day and often went hungry into the bargain, that this intellectual peacock might look the part. Matthew Arnold contemptuously referred to the machine of his day as "producing an unspiritual civilization," while Victorian England

constantly preached the return to nature and the simple life of renunciation. In an earlier day in the life of this Republic, a wisdom-laden school board out in Ohio refused to allow a group of young people in the neighborhood the use of the school house for a debate as to whether railroads would be a good thing for Ohio on the grounds that if the Lord had meant for people to ride through the countryside of Ohio at the death-dealing rate of twelve miles per hour, he most certainly would have said something about it in the Bible. Many years later, a goodly old farmer in the same State refused to buy a mowing machine from a traveling salesman on the grounds that the Bible says, "In the sweat of thy brow shalt thou eat bread," and since no man could possibly sweat riding a comfortable seat while mowing his meadow in Ohio, he would have none of this machine stuff. It is not of record why the salesman did not tell him the Bible is also silent on the matter of smoking a pipe. He probably never had attended a short course in salesmanship! Laborers in England as late as 1860 went into the mills of England and broke up the machines in the textile mills. Basically, this is the same argument which we use when we attempt to limit production by individuals to make the job last longer.

And so it goes. The machine is anathema. Our intelligentsia, that interesting group among us who are so busy formulating a philosophy about life which will justify themselves in having nothing to do with it, that they have no time left to take any part in it, have gone into the automobile factories, have there counted the holes a man can drill in a wheel-rim in one minute with an automatic drill. Being good at figures, they multiply this by 60 and this by 8 and this by 6 and, having conclusively arrived at an astoundingly enormous number of holes the man can drill in a week, they instantly conclude that this is too many holes and that the machine is, therefore, a monster. Being as clever with words as they are with figures, they proceed to write vehemently of a "mechanized civilization," a "machine-bound man," "handcuffed to the machine" with such other appealing notes in supposed defense of the poor, enslaved, bedeviled, "machine-cursed" laborer, that they drive tender-hearted ladies to tears and reformers to the platforms.

Our progress has produced growing pains. Masses of men have confounded the natural adjustments of a rapidly developing technique based on science and the machine with an earlier technique based on handcrafts and have found fault with the newer tempo of life because it entertains different ideals and ways of living. To these, the machine is a Frankenstein Monster and will ultimately destroy us. It should be enough to observe that the original "Monster" was only a fiction and that the modern machine is the most altruistic thing in modern life.

But the critics pile Ossa on Pelion. The machine has given us our factories. Factories have given us our cities. Cities have given us our business system, and our business system has given us our wealth. It is no matter to the intelligentsia that all civilizations are city-made. They cynically exclaim that business adds nothing to civilization; that business is a distressing force and that loftier aspirations are crushed by it. Industrialism and avarice are "buddies" and "clinking coins have no place in the music of aspirations." We are told that the marketplace is no place to look for civilization. Business and the "machine civilization" which produced it are both bad, and "soul-killing" industrialism is terrible. "Big Business," which seems to be in hiding just now, is especially distasteful to the critics of the machine, though I have no doubt they will be glad to see it when it reappears.

Of course the facts are that "Big Business" is relatively smaller today than ever before in the history of the world. One dollar out of every four we earn in this country goes to 50,000 tax-gathering and tax-spending agencies, in addition to hundreds of millions more for philanthropy, our tenth ranking industry. So it is, that a larger proportion of our wealth goes for culture than was true of any nation in the ancient world. We are told that the total income of Rome for any one year in the Augustan Age was only 5 per cent. of New York City's last year's budget! What we have in this country is Big Culture, and if our intelligentsia don't watch out, they will discover who pays for their bread!

There is nothing new in any of this. The Bishop of Ripon and Goethe say exactly what Ghandi says. But having taken

a bicycle home with him from England, this modern saint will find he has started something he cannot stop, and by this act of improving his personal transportation he automatically disqualifies himself to speak with authority. We may charitably suspend judgment upon all these critics of the machine until we learn more about their mode of living. However, as a matter of courteous suggestion, born entirely of a desire to serve, we may be pardoned for suggesting that these gentlemen all take a trip to Thibet, Afghanistan, or Patagonia, where there is no machinery at all, and where there is no "tyrannous technique" to harass them.

However, some of this criticism needs examining. There are some features about the machine none too pleasant to contemplate. But it does have defenses, and they are soundly rational and historically accurate.

In the first place, it is a common fallacy that we have the only "*industrial civilization*" which has ever existed. On the contrary, all civilizations have been industrial. There is no other way for them to exist. They have differed only in degree and intensity and the variations in them have been determined almost entirely by the *wants* of men at a given time.

The quality of life and the culture produced has invariably depended upon the success of the commercial and industrial period and its duration. The greater the wealth produced in the period, the greater the contemporary culture. And culture is always contemporaneous with the commercial and industrial growth of any civilization.

Phoenicians sent caravans trading to the Orient. Incidentally, they brought back an alphabet and sent culture on its way a thousand years. Culture always follows business. Business has been the forerunner of every great civilization which the world has known.

But, more specifically, the intelligentsia tell us:

1. *That there is no beauty in the machine.*

Poets like ready-made metaphors. The Leviathan has no creaky wooden hull, no greasy decks, no knotted cordage, no patched canvas bellying to the breeze. So the modern poet turns up his nose at her because her comfort is too comfortable;

her efficiency too efficient; her safety too safe. A Viking Long Boat would inspire this modern poet, but not the Europa. The facts are, however, that the automobile is as beautiful as any chariot ever driven by ancient charioteer, and the modern liner surpasses in beauty any fantastic tub that ever tested cordage or the courage of a mariner, while the airplane is as beautiful as the flying bird itself, and a modern passenger engine is a work of art.

2. *The machine destroys artistry in the product.*

On the contrary, the machine is democratizing art. The man in the street today wears a more artistic shoe than Henry VIII; and the King picked his shoes with the same discriminating care he did his women. A modern electric range is a more artistic piece of furniture than the dressing table of Mary, Queen of Scots, if only you forget we use the range to fry bacon and she used the dressing table to make up on. Through the reproduction of artistic tapestries in wallpaper, the machine has made it well-nigh impossible to go into a first-class paper store and buy an ugly roll of wallpaper. The machine is not destroying art. It is democratizing it by making accessible to all men artistic forms of the necessities and luxuries of modern life.

Fundamentally, this is the objection the intelligentsia have to the machine. It is making art, learning and leisure accessible to all men, and hitherto these have been the exclusive prized possessions of the intellectual classes. The products of the machine are artistic.

3. *There is nothing human in the machine.*

It is crushing the life out of men, reducing them to mere robots, keeping them "handcuffed to the machine," making mere automatons of them. This is just too bad! The facts are the machine is the most humane thing yet contrived by man, and has far outstripped his philosophy or his altruism in freeing man from arduous toil and slavery. Aristotle accepted human slavery as did our own forebears. The altruism of the Christian religion, with the challenge of its master that all men are brothers constantly ringing in its ears for centuries, complacently accepted human slavery and

waited until the machine made the system economically impossible before "rising up to strike off the shackles" of human slavery.

To face a fact, it must be said that human slavery has persisted longest in those civilizations where the agrarian life was the predominant economic technique. So true is this, that even ex-slaves from America returning to Africa using only handcrafts and machineless agriculture have adopted a system which the machine liberated them from, and there is good evidence for the fact that many of the evils of tenant farming are nothing more than a throw-back from a slave agriculture, for the curve of tenant farming invariably diminishes as the curve representing the use of machines on the farm increases.

Time was not so long ago when 16 hours was a legal day's work. The machine has made this inhumane. Altruism never freed slaves. Where hand-labor, with its "ennobling influences" persists, the majorities are dangerously close to slavery yet. Any intelligent traveler will find this out if he will take a swing around the circuit outside Western Civilization where the machine has revolutionized norms of thinking, standards of living, and customs of conduct.

What the intelligentsia seem to want are "the good old days" when the cobbler worked at his bench 16 hours, ate three meals at his work, and lived in a stuffy, airless room and enjoyed his "creative freedom." Great stuff, that!

London, 200 years ago, was largely one of these "ideal handcraft" cities of the "good old days" variety. Then the industrial artists had "pride in their work" and disease in their systems—for the death rate under those "ideal working conditions" was 50 to each 1,000 of the population as against 12½ today under the machine. The machine has brought life, not death, as the critics of the machine would have us believe.

To our intelligentsia, wielding a sledge-hammer 10 to 12 hours a day in a sooty blacksmith shop is ennobling. But to sit on a comfortable seat in a well-heated and ventilated factory manipulating with a delicate lever a trip-hammer is very debasing.

The tenant farmer in America is nearer this "ideal handcraft" stage than any man among us. From 50 to 75 per

cent. of these must turn over half of all they have made to the landlord. Lord, deliver us from such "ideal hand-crafts"!

Oscar Wilde says, "The fact is, that civilization requires slaves. . . . Human slavery is wrong, insecure, and demoralizing. On mechanical slavery, on the slavery of the machine, the future of the world depends." Here is a poet with a sociological background. Here is real intelligentsiaism!

4. *That we are a nation of mere machine tenders.*

In 1910 we had 41,615,000 people employed in the United States; 7,972,000 of these were workers in factories, while 827,000 more worked at other enterprises connected with factories, giving a total of about 9,000,000 men and women engaged in working with and about machines. Of these nearly nine millions, the highest estimate we have seen of actual machine tenders is 4,500,000. Our population in 1910 was 105,711,000. The "machine tenders," therefore, amounted to only about 4½ per cent. of the population, or 13 per cent. of the total number of employed persons in the United States.

We do not concede it, but granting that this 13 per cent. of employed were more or less slaves to the machine, it is interesting to compare the conditions that existed in the Periclean Age of Greece, where there were 5,000,000 free men and 12,000,000 slaves. It took 70 per cent. of the population as human slaves to produce the Golden Age of Athenian culture, whereas only about 4½ per cent. of our population work at the machine, and I maintain it is neither so strenuous nor as enslaving as ordinary labor in the open fields or in the blacksmith shop.

As a matter of fact, machine tenders are decreasing. In 1928, there were 1,250,000 fewer men in factories than in 1923, and '28 was one of our busiest recent years. This does not mean that fewer men were at work, although popular opinion has put this construction upon it. It only means that fewer men were at work in factories and fewer men were *tending machines*, for during the same period we added directly more than 2,000,000 men and women to our payrolls, who were working at new trades and new enterprises which the higher development of the machine had made possible. Directly and indirectly, the figures are nearer 4,000,000.

5. *The factory system is undermining the health of industrial civilizations.*

It is interesting to observe that, with modern machines, ventilated factories and a regard for the health of the "machine bound" man, the healthiest occupation in all England is the manufacture of glue and fertilizer. The most modern machine on the horizon is found in the electrical field. The death rate among electrical workers is exactly 50 per cent. below that of the country at large. Following the glue and fertilizer workers, there come in order of health, electrical workers, preachers, gardeners, farmers, teachers, doctors, lawyers. It is suggested for health's sake, that the lawyers invent some machine for administering justice. It would be healthier and might be equally just! As a matter of fact, the workers in soap factories outrank in health all of the workers in the professions just enumerated. There has been a good deal of "ballyhoo" about the evil effects of the machine upon men's physical health and upon his mental and spiritual attitudes toward life.

The linotype machine was invented in 1887. At that time typesetters were working twelve to fourteen hours a day. By 1903, there were 7,500 of these machines in use. The hours for setting type had been reduced from 14 to 8. The wages increased 20 per cent. The death rate decreased 30 per cent. A very unhealthy thing, this linotype machine! As a matter of fact, the mental and spiritual outlook upon life is very closely related to physical health. Noting much of the choleric stuff now coming from the critics of the machine, and seeing that the health tables are all against them as compared with machine workers, we suggest that they take up tending the "deadly machine" for a while until they regain sufficient health to get their livers going.

Accidents are closely related to health. Today, in the "machine-made" world, there are fewer accidents to the man who works than ever before in the history of civilization. The records prove this in spite of the fact that in an earlier day only major accidents were reported while today all accidents are reported. One thread factory in this country went 10,000,000 man-hours without a lost-time accident. Many plants go for months and years with not so much as one lost-time accident.

Mr. Frederick Ecker's Metropolitan Life Insurance Company has just announced among its industrial policy holders the lowest death rate in all history. Abe Martin says somewhere in his collection of classical nonsense that it is funny how a man with facts can break up an argument. This Metropolitan fact is just too bad for critics of the "deadly machine."

6. *The machine throws men out of work.*

Philosophically, the best answer to this criticism is, that this is exactly the glory of the machine—it does the work of men and thus releases them for more interesting pursuits. Many idealists wish it were possible to do all the work of the world with the machine. It has already demonstrated its usefulness by abolishing actual human slavery and releasing other millions from 14 to 16 hour days to 8 and 9 hour days.

But that the machine "throws men out of work" is another one of those "perfectly self-evident propositions" which does not happen to be true.

Turning to England for a moment, because the figures have been carefully recorded there by the Government for more than a hundred years, and taking its largest industry, textiles, we find that it took 320 persons to spin as much in 1769 as one man could spin in 1840. But in 1855, just 15 years later, one man could spin as much as 700 men could spin in 1769. Arkwright invented the first spinning machine in 1855. That is the year we have one man spinning as much as 700 men could spin just 86 years before. According to the argument of the man in the street, this is throwing 699 men out of work in the lifetime of one octogenarian. But this is a piece with much of the logic of the man in the street. He feels his thoughts. But have a look at the facts in the case:

TABLE I.

In England.

Year.	Men Employed in Textile Industry.	
1835	218,000	
1847	316,000	
1850	331,000	
*1856	*379,000	(Year after Arkwright invented first spinning machine)
1862	451,000	
1870	450,000	
1874	479,600	
1878	483,000	
1885	504,000	
1890	526,800	
1895	538,900	
1907	677,000	
1914	689,000	

There was a steady growth of employment in an industry in which the improvement of the machine was going forward at a faster rate, perhaps, than the machines of any other industry. But this does not tell all of the story. In 1831 the population of England was 24,028,584. By 1911, the population had grown to 45,221,615. This means that while the population was *doubling*, the cotton workers were *trebling*. This does not look as though the improved machine was causing unemployment. But someone will advance the idea that the cotton trade in England presents the exceptional case. I wonder if it does.

The makers of machines, tools, engines, mill-wrights, fitters, watchmakers, turners, and such like people have had the same experience. In England, the 14 "Engineering Trades" show the same thing. Let's have a look at what has happened to these workers:

TABLE II.

Number of Persons Employed.

Year.	Males.	Females.	Total.	Decennial Increases.
1871.....	222,594	12,900	235,584	
1881.....	253,994	13,982	267,976	13.7%
1891.....	323,327	18,904	342,231	27.7
1901.....	507,782	22,738	530,520	55.0
1911.....	564,994	37,413	602,407	13.5

Here again, we have the same result. The number of persons employed increased all the time while the machines were being improved all the time. A mere glance at the decennial increases shows that the number of people employed in 14 engineering trades in England increased much faster than the population increased. Taking the four periods in which the percentage of increase could be figured, the last four, we find that the average increase for the four is 27.475 per cent., which, of course, is far beyond the populational increase for the same period.

But there are also figures for the trade that has made the most rapid advance in perfecting the machines, the printing trade. The advance in technique in this trade has been little

short of marvelous. Yet when the figures for printing and distribution of the product are taken into consideration, the same conclusion is reached. It is estimated that the man-hours necessary now to bind a thousand books are only one-third of what they were just thirty years ago. There are figures on this trade which show that improving the machine *puts* men and women *to* work, *not out* of work.

Examine the following table—figures taken from the English census again:

TABLE III.

Number of Persons Employed.

Year.	Males.	Females.	Total.	Decennial Increase.	Publishers, Book-Sellers and News Dealers.
1871..	57,484	8,587	66,071	—	14,163
1881..	74,542	12,941	87,483	32.4%	16,865
1891..	102,082	19,125	121,207	38.5	23,394
1901..	119,834	29,959	149,793	23.5	31,972
1911..	140,968	43,107	184,075	23.0	40,847

These figures show a constant increase of employment even at a more rapid rate than the populational increases.

Truth is, that most of our apprehensions about the machine putting large numbers of people out of work is based on the false assumption that demand for goods will become stationary. Quite the reverse is true. There is no good reason for assuming that desire for the good things of life will suddenly cease. Thirty years from now, huge fortunes will be made out of new patents not now in the Patent Offices of the world.

Now printing, with the engineering trades, is perhaps most subject to the influence of invention. The most cursory examination of the advance in technique in these trades will reveal a real epic of progress. Combining printing and engineering trades in England, and calculating the percentages of increase in employment in them over a period of forty years, we get *not unemployment*, but a steady *increase* of *employment*.

Only once did population increase faster than the number of persons engaged in engineering. This was the period from 1871 to 1881. But these trades more than made up for this

TABLE IV.

Year.	Populational Increase.	Increase in Engineering Trades.	Increase in Printing.
1871.....	13.21%	—	—
1881.....	14.36	13.7%	32.4%
1891.....	11.65	27.7	38.5
1901.....	12.17	55.0	23.5
1911.....	10.89	13.5	23.0

decennial in the three following periods. From 1891 to 1901, the engineering trades increased the workers by 55.0 per cent. The printing trades have had a steady increase, which only means that more people were reading and were being told in much of what they read that the machine was going to upset civilization! At the very time, it was employing more and more men to print and distribute the very stuff designed to show what an awful menace a modern press is! It is not very convincing.

It is revealed by British statistics that the total number employed in industry (and all trades affected by the invention of new and modern machines are included) increased during the thirty years between 1881 and 1911 from 6,373,000 persons to 9,468,000. This is the astounding rate of 48 per cent. for the period. But the population of England for the same period increased only 38 per cent. But for the strident voices of the calamity howlers, the ghost of unemployment *as caused by the machine* could be forgotten. Of course the fact is that but for the machine, England's population could not have increased 38 per cent. in the thirty-year period between 1881 and 1911. And for a very good reason. The country could not possibly have supported them. Starvation, or peasant standards of living for all, is the alternative right now between that state and the best machines possible.

The causes of our present unemployment plight cannot be charged to the machine. There are plenty of other reasons for this depression. Some people have become so excited about the machine they are not thinking. Wanting a scapegoat, they approach the thicket and lo, the machine!

Coming to a consideration of some home figures, what do we find? Throughout the history of the industrial era, this

problem of the repercussions of greater efficiency in manufacturing processes incident to the use of machines has been ever recurring. To epitomize the development of productivity from 1919 to 1925, both for industry and for the individual worker, the Department of Commerce has given us the following summary, in Table V:

TABLE V.

Index of Increased Productivity in Manufacturing Industries 1925.
(1919 equals 100.)

Vehicles for Land Transportation.	Physical Volume of Production.	Number of Persons.	Primary Horsepower.	Production Per Person.
Vehicles—Land Trpt	283.3	108.3	182.5	220.0
Rubber	158.3	79.7	152.8	199.3
Metal and Metal, Products other than Iron and Steel	132.4	81.2	114.0	163.1
Stone, Clay, Glass	179.1	115.1	151.5	155.6
Tobacco Mfg	124.4	79.9	97.0	155.7
Chemical, Allied Products	140.6	91.8	147.1	153.2
Food and Allied Products	116.4	81.3	115.8	143.2
Paper and Printing	152.8	108.8	131.1	140.4
Iron and Steel	131.5	95.6	114.1	137.6
Lumber	113.6	94.1	86.9	120.7
Textile and Products	119.3	104.5	126.6	114.2
Leather and Its Mfgs	93.4	90.6	106.9	103.1
Ship and Boat Bldg	7.0	13.3	54.8	51.8
All Industries	128.6	91.4	121.8	140.7

Again, on the basis of 1914 as 100, the following table shows the advances in the output per worker in certain leading industries for the period 1914 to 1925:

TABLE VI.

Industry.	Per Cent. Increase in Individual Output.
Iron and Steel Industry:	
As a Whole	59
Blast Furnaces	54 (to 1923)
Steel Works and Rolling Mills	59
Boots and Shoes	6
Leather Tanning	26
Slaughtering and Meat Packing	27
Petroleum Refining	83
Paper and Wood Pulp	34
Cement Manufacturing	61
Automobiles	172
Rubber Tires	211
Flour Milling	36
Cane Sugar Refining	28

Meanwhile, for the same period, productivity for steam railroads increased 40 per cent. per man-hour, train and engine crews alone about 34 per cent. In bituminous coal mining, the individual efficiency increased 25 per cent. between 1915 and 1925. There has been increased efficiency caused by better management and more modern machines. Far from being a cause for criticism, it is a consumation devoutly to be wished.

The National Industrial Conference Board, in making a study of mass production in the United States recently, brought to light some interesting facts in Comparing the United States with Great Britain. The Board takes eight leading industries and compares the horsepower per wage earner, and the value added per wage earner and finds that the advantages in production and value added are all with this country. It also finds that there has been little increase in mechanization of industry in Great Britain for the 17 years ending 1924. But in these eight leading industries, it finds on the basis of 1913 prices the output per worker in 1917 was $1,540 in England as against $1,740 in 1924, an increase of $200 or 13 per cent. per worker. During practically the same period, we had an increase per worker of 35 per cent. The Board states, "Eight selected major manufacturing industries in the United States which use an average of 1½ as much horsepower per wage earner employed as do the same industries in Great Britain, turn out, largely as a result of this greater use of power, from 2½ to 3 times as much production per wage earner employed. This greater productivity per worker accounts largely for the higher wage levels and living standards prevailing in the United States. . . ." Now it will be evident that, in spite of the greater *mechanization of industry* in this country than prevailed during the same period in Great Britain, unemployment began in Britain before it did here, attained its worst proportion sooner than it did here, and has retained its greater magnitude in proportion to the number of employed persons. If the machine has been the cause of our present unemployment, as a Cabinet Member and at least two of our United States Senators recently declared, we should have far outstripped Great Britain, as our mechanization since the World War has been much more rapid. But this is not the case.

This advancing efficiency, and the drop in American industry from wartime inflation, had between 1920 and 1928 put 917,000 men out of work. I am using Government figures, Department of Commerce. If to these we add 800,000 in the decline of employes in agriculture, only a part of whom may be charged to machines, and the 240,000 relieved from railroads, we arrive at a formidable figure of nearly 2,000,000.

Too many social reformers are overwhelmed with these figures and go no further. But it is only half of the story.

For instance, between 1920 and 1928, there was an increase in the number of workers in servicing and driving automobiles of 760,000, including 100,000 bus drivers, a vocation which did not exist in 1914. There were 100,000 more insurance agents in 1928 than in 1919. These additional men were made necessary by the large expanse which took place in insurable fields incident to new industry and trades. Electric refrigeration, light and power, and oil heating establishments have increased employment by another 100,000. Between 1919 and 1928, another 100,000 were added through construction work and management. There were 232,000 more teachers and professors required to look after the young in 1928 than in 1919. Motion picture servitors (not production employes) added another 125,000. Barbers and hairdressers to the tune of 170,000, and personal service in hotels and restaurants, 750,000, and radio, 200,000.

Thus it appears from the facts that, while we were displacing in America 1,957,000 people through increased efficiency made possible by the machine, we were *adding* in *new trades* and *professions* 2,527,000 people! The difference just accounts for the increase in population during the period. Hence it is that as the machine becomes more and more efficient, the new service functions not only offset unemployment, but indicate a larger per capita earning power and thus increase the standards of living.

The machine plus brains equals goods, comforts and wealth. This formula increased factory production almost 60 per cent. between 1900 and 1925, and the same thing happened on the railroads, in the mines, and on the farms. The perfection of the tool has measured the speed of man's upward journey from

the Stone Age to now. Considering all industries in the United States, 71 workers in 1925 could produce as much as 109 could produce just 25 years before, and while working from 5 to 10 per cent. less time. Just here is the crowning glory of the machine. Let us be quick to admit that the productive output per worker has increased, that fewer men in a given field can do more work. But having admitted this much, there is no use being stampeded by the intelligentsia. To reduce the hours a man works in this world has always been considered a desirable thing to do. If the machine enables him to do more work in less time, it proves itself humane, not a menace.

If this criticism of the machine were confined to journalistic opinion it would be bad enough. But when a Cabinet Officer and a United States Senator inject it into debate and ascribe our present unemployment to its baneful influence, it becomes just too bad. They are even quoting figures from railways and industry to prove their point. However, they say nothing about unemployment in fields where little or no machines are used and conveniently overlook the new fields for labor brought in by the machine. The hammer chorus is growing louder and is anything but harmonious.

We must also admit that a similar relative contraction of the number of employed took place in railroading, mining, and other enterprises. Though it must be said in defense of the machine that much of the mine labor was not needed because of a decline in the demand for coal.

The total decline in men employed in manufacturing between 1920 and 1928 was 917,000, which added to those displaced in railroading, mining and farming gives us approximately 2,000,000 men displaced through over-expansion incident to the war and the increased efficiency of the machine and factory management.

Admitted. These are only fractional data. But they are much more convincing than the Frankenstein Monster talk. They prove somewhat conclusively that as the machine grows more efficient, hours of labor grow less, goods get cheaper and better, and the only limitless thing in the world, human wants, expands to demand sufficient additional goods to keep everybody at work, provided we behave as we should.

"Technocracy" has recently given us some interesting statistical evidence for what we have all along known in a general way. The technique for obtaining a living and the amount of living obtained per person changed very little from the dawn of history until about 1800, say; but now we find the average citizen of the United States consuming 75 times what he did in 1800, and about 66 per cent. of this increase has been in one generation, or since 1900. Some assume our present distress is due to this large use of energy, and predict worse to come. This is equivalent to saying a man should work 12 or 14 hours per day with his hands to get food, clothing and shelter, and poor food, poor clothing and poor shelter at that, as he did in the days of Menes, Alcibides, or Napoleon.

"Technocracy" affirms that besides the 2,000 calories a day necessary for existence, man is now using 150,000 calories in addition to the 2,000 he consumes as food. This is good. It means that after some 7,000, or more, years of life on 2,000 calories, and frequently bad calories at that, as, for instance, putrid meat before the days of refrigeration, the evidence of which may be observed about the middle of the figures on any English etching of reasonably early date, man made up his mind to live some and went out and dug up 150,000 more calories which, while he could not eat them, were very useful in supporting homes, colleges, radios, travel and as thouand and one other things more or less useful and always interesting. The same authority quotes more figures to show how very rapidly we have developed energy for our uses, and adds that if we used the most efficient method of production only 30 per cent. of the people now employed would be needed to do the job. Since about 38,000,000 now work in normal times the most efficient methods would mean 20,000,000 people would not be needed unless new inventions should bring in new enterprises. This would make a jobless army, indeed!

But there is no need to surrender the point so quickly. If 30 per cent. of our present workers can do all we need done, it should be quickly welcomed. For it is a simple device to keep all workers and shorten the hours, thus providing leisure for any sort of creative work the soul desires.

The same authorities apply their findings to the automobile industry, saying that had it not been for the improved methods

in that industry, the industry alone would have offered work for from 2,500,000 to 4,000,000, just about the number added by population growth since 1904. What is overlooked here is that you cannot use more than 10 per cent. of your total working force to supply you with *only one means* of transportation and get away with it. The cost of cars under such a program would make them prohibitive to the average man.

Professor Charles A. Beard has recently said, "A knowledge of the good life is our certain philosophic heritage, and technology has given us a greater power over nature which enables us to provide the conditions of the good life for all the earth's multitudes. That seems to me to be the most engaging possibility of the drama, and faith in the potentialities keeps me working at it even in the worst hours of disallusionment."

Since Edward Carpenter wrote his "Civilization, Its Cause and Cure," and tried to exemplify to Victorians what he was talking about by living outside the conventional creed of his day, we have had plenty of critics of our civilization by people from the outside. Morris, Ruskin, and a thousand others have indulged themselves thus. But only recently, Sir Alfred Ewing, immediate President of the British Association for the Advancement of Science, has spoken from the inside and he declares with reference to science, "The command of Nature has been put into Man's hands before he knows how to command himself." Discovery and invention have moved with lightning-like rapidity during the last one hundred years. But this is nothing to be excited about. Our material advance always leads the way for institutional change. I have no apprehensions about our ability to control science and to properly use the machine. Indeed, the very rapidity with which science and the machine have moved is good for us. It makes possible what will be the greatest cultural advance the world has ever known.

But the machine has some positive arguments it may modestly advance to justify its place in the sun. In the first place, it is a great educational force. It has reduced the physical fact of this world to a readily reached neighborhood and the mental, racial, economic and political facts of the world to a community problem. It has widened the outlook and emphasized the relations of men. Isolation is now as

simple as it is impossible. The railroads, autos, and airplanes are taking us everywhere. The telephone, telegraph, and the radio are telling us everything. Today, the workers' relation to the world is what it used to be to his little community, and for the first time in human history the working man has been given some leisure to read, study and develop a hobby. The machine has been a fairy godmother to the toiler. Today the problem of education is not so much to teach the man how to work, as to teach the wise use of the leisure the machine has given him.

Psychologically, there is something in the machine which calls out the best there is in us. If you drive a car yourself, you are alert, observant, active. There are definite character-building processes going on in such an enterprise. The comfort of the machine is something. The reaction of the human being to it is much more. The machine forces and demands a certain amount of intelligent interest. Machine workers rarely go insane. Few of them find it necessary to leave their jobs because of mental disorders. In well-organized industry, there are recreational opportunities such as play-grounds, tennis courts, moving pictures, cafeterias where ideas are exchanged and social intercourse indulged in, and many other opportunities for wholesome living.

In this connection, it will be helpful to observe that approximately 90 per cent. of the women confined in asylums of the Southeast are for melancholia, and come from the quietude of the farm—so beautifully written about by the poets, and on which so few poets care to live.

There is no danger that the machine will master the man. The man created the machine. He will be silly indeed to let it master him. The triumph of the material over the spiritual would be a tragedy. We have traveled faster and gone farther toward providing the material comforts of life in a hundred years than the Old World did in forty centuries. There is some evidence among us of sensation hunting. This is too bad. But it is a mere rash. We like sensations. Our heroes must be giants. Our recreation must be hair-raising, our social life showy and spectacular, and our religion "hell-busting." This is the result of the speed by which we have come where we are. But it is not so bad. Our very speed has

brought us to the gates of a sparkling culture. The materialistic splendor of the background assures an original cultural pattern. It will be the best unwritten culture the world ever saw. The "deadly machine" is responsible for the background. America is young. It is scarce 300 years since the Pilgrims landed here. We are still adolescing. But what a soil, what a country, what a wealth to carry a new culture!

A MECHANISM OF ACQUIREMENT OF COSMIC RAY ENERGIES BY ELECTRONS.

BY

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BARTOL RESEARCH FOUNDATION
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It is usually considered that the assumption of the existence of electronic energies of the order 10^{10} volts is attended with considerable theoretical difficulties. The present note is an elaboration of one of the suggestions recently made by the writer.[1] It concerns the possibility of the production of cosmic ray energies in stellar spots, analogous to sunspots on our sun. It is known that the sunspots possess considerable magnetic fields which grow in comparatively short intervals of time. A consideration of the existing magnitudes will show that line integrals of the electric field of the order 10^{10} volts may readily arise through the Faraday law as a result of the growth of such magnetic fields. However, the detailed working out of the matter involves certain considerations which require careful attention.

We shall consider the problem in cylindrical polar coördinates r, θ, z, in which the stellar spot is in the plane of r, θ, and the magnetic field H is symmetrical with θ and of course more or less perpendicular to the plane of the spot.

The problem must be treated from the standpoint of relativistic electrodynamics. It may be conveniently treated by the equations of Lagrange or even more conveniently by the Hamiltonian equations.

The Lagrangian function for an electron in a field specified by a vector potential U and a scalar potential φ is, as is well known

$$L = -mc^2(1 - \beta^2)^{1/2} + \frac{e}{c}(U \cdot u) - e\varphi,$$

[1] In a paper under the above title presented at the Chicago Meeting of the American Physical Society, November, 1932.

where m is the rest mass, u is the velocity, and $\beta^2 = u^2/c^2$. φ is zero in our problem, so that transforming to polar coördinates, we have

$$L = -mc^2\left(1 - \frac{r^2\dot{\theta}^2}{c^2} - \frac{\dot{r}^2}{c^2} - \frac{\dot{z}^2}{c^2}\right)^{1/2} + \frac{e}{c}(\dot{r}U_r + r\dot{\theta}U + \dot{z}U_z).$$

The moments P_r, P_θ, P_z, are given by

$$P_r = m\dot{r}(1 - \beta^2)^{-1/2} + eU_r/c, \tag{1}$$

$$P_\theta = mr^2\dot{\theta}(1 - \beta^2)^{-1/2} + erU_\theta/c, \tag{2}$$

$$P_z = m\dot{z}(1 - \beta^2)^{-1/2} + eU_z/c. \tag{3}$$

The Hamiltonian function $\mathcal{H}$ is given by

$$\mathcal{H} = \dot{r}P_r + \dot{\theta}P_\theta + \dot{z}P_z - L \tag{4}$$

and is easily shown to be

$$\mathcal{H} = mc^2(1 - \beta^2)^{-1/2}.$$

Solving (1), (2) and (3) for $\dot{r}$, $\dot{\theta}$, $\dot{z}$, and substituting in (4) we readily find

$$\mathcal{H} = mc^2\left\{1 + \frac{1}{m^2c^2}\left[\left(P_r - \frac{e}{c}U_r\right)^2 + \left(P_z - \frac{e}{c}U_z\right)^2 + \left(\frac{P_\theta}{r} - \frac{e}{c}U_\theta\right)^2\right]\right\}^{1/2}. \tag{5}$$

Now in our problem $U_r = U_z = 0$, and U_θ is independent of θ for a magnetic field symmetrical with regard to θ. In fact, the electron currents responsible for U are all of a circular type symmetrical about the z axis. Thus P_θ is constant, i.e. from (2)

$$mr^2\dot{\theta}(1 - \beta^2)^{-1/2} + erU_\theta/c = er_0U_0/c, \tag{6}$$

where r_0 and U_0 refer to the values of r and U_θ at the instant when $\dot{\theta} = 0$. Thus

$$\mathcal{H} = mc^2\left\{1 + \frac{1}{m^2c^2}\left[P_r^2 + P_z^2 + \frac{e}{c}\left(\frac{r_0}{r}U_0 - U_\theta\right)^2\right]\right\}^{1/2}. \tag{7}$$

Now $\mathfrak{K}$ is explicitly a function of t through U_θ. Hence, as follows directly from the Hamiltonian equations

$$\frac{d\mathfrak{K}}{dt} = \frac{\partial \mathfrak{K}}{\partial t}$$

$$= -\frac{e^2}{\mathfrak{K}}\left(\frac{r_0}{r}U_0 - U_\theta\right)\frac{\partial U_\theta}{\partial t}$$

$$\frac{1}{2}\frac{d}{dt}\mathfrak{K}^2 = e^2\left(U_\theta - \frac{r_0}{r}U_0\right)\frac{\partial U_\theta}{\partial t}. \tag{8}$$

Since

$$\mathfrak{K} = mc^2(1-\beta^2)^{-1/2} = T + mc^2,$$

where T is the kinetic energy,

$$\frac{1}{2}\frac{d}{dt}(T+mc^2)^2 = e^2\left(U_\theta - \frac{r_0}{r}U_0\right)\frac{\partial U_\theta}{\partial t}. \tag{9}$$

Hence T increases with t so long as $rU_\theta \geqq r_0U_0$. This is certainly satisfied at the initial instant in view of the definition of r_0 and U_0. It will be satisfied for all subsequent instants if

$$\frac{d}{dt}(rU_\theta) \geqq 0,$$

i.e., if

$$\frac{\partial U_\theta}{\partial t} + \frac{\dot r}{r}\frac{\partial}{\partial r}(rU_\theta) \geqq 0,$$

i.e., if

$$-(E_\theta - \dot r H_z/c) \geqq 0. \tag{10}$$

Bearing in mind that E_θ is in the negative direction of θ for an increase of U_θ in the positive direction of θ, we see that condition (10) is simply the condition that the force due to the electric field accelerating the electron in the negative direction of θ must be always greater than the force due to the magnetic field which acts in the opposite sense when $\dot r$ is positive. If (10) is satisfied always, the electron will never loop around in its path since to so loop $-(E_\theta - \dot r H_z/c)$ would have to be less than zero in order to balance the centrifugal acceleration at the instant when $\dot\theta$ was zero. Since $\dot r$ can never exceed c, the condition for continual increase of energy will always be satisfied if $|E_\theta| > |H_z|$. If there is anything like a uniform

growth of magnetic flux with time, E will certainly be greater than H initially, and we shall find that there is plenty of time for high electronic energy to be acquired before H has grown to a magnitude sufficiently large to prohibit further increase.

If the electron starts from rest, at $t = 0$, and if the magnetic field is zero, then we have $U_0 = 0$, and

$$\frac{1}{2}\frac{d}{dt}(T + mc^2)^2 = e^2 U_\theta \frac{\partial U_\theta}{\partial t}. \tag{11}$$

So far we have made no assumption as to the way in which the magnetic field H depends upon r. Since $H = \text{curl } U$, Stokes theorem applied to an annulus $2\pi r dr$ perpendicular to z gives

$$2\pi r H_z = \frac{\partial}{\partial r}(2\pi r U_\theta). \tag{12}$$

If, for purposes of illustration we take a case where H_z is inversely proportional to r, we shall enjoy the advantage of having U_θ independent of r as well as of θ. We shall consequently write

$$H_z = \frac{H_0 R t}{r\tau}, \tag{13}$$

where τ is the time taken for it to acquire a field intensity H_0 at some assigned radius R comparable with the radius of the spot.

With U_θ independent of r and $U_r = 0$, $\mathcal{H}$ is independent of r, so that P_r is constant with time, which, through (1) shows that $\dot{r}$ is zero for all time since it is zero initially. Thus the electron describes a circular path. As a matter of fact an examination of the equations shows, as might be expected, that under these conditions the centrifugal acceleration of the electron and the magnetic deflecting force increase together with the time in such a manner as to keep each other balanced.

Thus, with the assumption involved in (13), (12) gives $U_\theta = H_0 R t/\tau$ and (11) gives

$$\frac{d}{dt}(T + mc^2)^2 = \frac{2e^2 H_0^2 R^2 t}{\tau^2} \tag{14}$$

and

$$(T + mc^2)^2 = \frac{e^2H_0^2R^2f^2}{\tau^2} + m^2c^4.$$

Since T is zero when t is zero.

For the energies in which we are interested, energies of the order 10^{10} volts, mc^2 is negligible, so that

$$T = eH_0Rt/\tau$$

or, expressed in volts

$$V = 300H_0Rt/\tau.$$

If $R = 3 \times 10^{10}$, $H_0 = 2000$, $\tau = 10^6$, $t = 1$ second, we find $V = 2 \times 10^{10}$ volts.

The conclusion is then to the effect that in one second during the initial formation of a stellar spot about 50 times the earth's diameter and of such character as to give rise to a magnetic field of 2000 gauss in 12 days, an electron can acquire a velocity comparable with 2×10^{10} volt. The electric field E is given by

$$\int_0^R \frac{H_0R}{r\tau} 2\pi r dr = 2\pi RcE,$$

so that $E = H_0R/c\tau$ and the magnetic field at the end of a time t is H_0t/τ. Hence in the present instance, the magnetic field would only just have attained a value equal to the electric field by the time the electron had received 2×10^{10} volts velocity. In the present case, the fact that $\dot{r}$ is zero insures that the electron would go on acquiring energy continually, even after the magnetic field had become equal to or greater than the electric field; but, this feature is special to our particular assumption as to the dependence of the magnetic field upon r. Naturally our particular assumption regarding H is mainly relevant to the mathematical simplification of the problem alone and not to its essential features. As a matter of fact, the magnetic field we have assumed would not have zero curl, and would require the existence of circular electron currents in the regions where H has the property specified. Difficulties regarding the infinite value of H at $r = 0$ are irrelevant since we only require the variation of H with r

postulated to exist over a very thin range of r. If we had a uniform angular field instead of one of the type assumed, the electron would not describe a circular orbit but would diminish the distance from the origin in its path. This complicates the details of our calculation but not the order of magnitude of the results.

We have given no attention to the motion of the electron parallel to z. It is obvious that since the electronic motion takes place in the opposite sense to that of the increasing electronic currents which are producing the magnetic field, the electron will be repelled from them, and so will shoot out into space, which is a desirable consummation from the point of view of our theory.

An examination of the foregoing calculation shows that it would be difficult to secure energies of 10^{10} volts from spots of a size such as occur on our sun. However, energies one-tenth of this amount are within the range of possibility. This fact is particularly interesting in suggesting that while we may have to look to stars other than our sun for sources of cosmic rays, the spots on the sun may be able to furnish electrons such as could play a part in auroral phenomena, since the position of the auroral zones suggests energies of the order of 10^9 volts for the electrons producing auroras. It is moreover a significant fact in this connection that correlations between sunspot activity and auroral and terrestrial magnetic phenomena have been observed. Another matter of significance arises from the fact that although, for purposes of visualization of the situation, we have imagined a spot which grows 2000 gauss in 10^6 seconds, as a matter of fact the electronic energy of 2×10^{10} volts is acquired before the spot has been growing for more than one second, or before the field has attained a value of more than 2×10^{-3} gauss in our example. Naturally it is not intended to imply that a situation exists in nature in which the problem we have cited is duplicated in all its details. All that is intended to be shown is that with magnetic fields extending over large areas in stellar spots, relatively small rates of change of these fields existing for brief periods can give rise to large electronic energies. Our problem has been designed to illustrate the feasibility of the idea in one particular case.

Finally, we must consider the possibility of loss of energy

by collision. The work done on the electron over its mean free path λ is $E\lambda c$. In our present example $E = RH_0/\tau c = 1 \times 10^{-3}$ e.s.u. Hence the work estimated in volts is $10^{-3} \times 600\lambda = 0.6\lambda$ volts. Hence if λ were greater than 50 cms. the electron would acquire more energy over its mean free path than it would lose at collision and the energy would continue to increase with time. The pressure above the surface of a star falls off very rapidly with distance and is probably far below that corresponding to a mean free path of 50 cms. in regions which are sufficiently near to the surface to experience the magnetic fields of the spots. It is probable therefore that the efficiency of the process of accumulation of energy is but little reduced by collisions.

The Rotojector.—(*News Edition, Ind. & Eng. Chem.*, Dec. 10, 1932.) The Rotojector is the name of a very ingeniously contrived centrifugal especially designed to give a continuous separation of solids from liquids. In the ordinary type centrifugal such a separation process is intermittent, it being necessary to stop the bowl every so often and clean out the accumulated solids. The outstanding feature of this newly developed machine is that the solids are ejected while the machine is running at top speed. All this is accomplished by virtue of a specially constructed bowl. This bowl is hollow-walled or provided with a special space that is entirely unconnected with the interior separating chamber. In addition, the bowl is constructed of segments held together by eight springs. These springs are strong enough to keep the bowl intact while rotating during separation of the liquid from the solids. However, when water is allowed to flow into the special space, sufficient hydrostatic pressure is developed to overcome the forces of the springs and the segments of the bowl come apart allowing the separated solids to escape. The disengagement of the bowl segments also permits the water to escape, removing this additional applied hydrostatic pressure and the bowl immediately closes. The pressure amounts to about 9 tons, but is so quickly generated and released that the opening and closing of the bowl are accomplished within 10 seconds. Liquids containing solids up to 10 per cent. by volume are readily handled by the Rotojector and the size weighing 930 pounds can take care of 700 gallons per hour.

C.

Flame-Proofing Wood.—(*News Edition, Ind. & Eng. Chem.*, Dec. 20, 1932.) In the Germany news-letter by WALTER ROTH we read that C. G. SCHWALBE AND K. BERLIN recommend sodium acetate with or without the addition of disodium phosphate as a new cheap flame-proofing for wood. Most effective impregnation is secured by treating the green, or air-dried, lumber with a solution of the salt under pressure. For structural timber, sufficient protection can be obtained by dipping in the salt solution; by applying it to the wood in several coats or even by spraying under certain conditions. A 15 per cent. solution of the anhydrous sodium acetate is quite suitable.

C.

PROBABILITY AND THE EXPONENTIAL LAWS OF PHYSICS.

BY

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In view of the modern trend toward statistical interpretations of certain physical phenomena, the following derivation of the exponential laws from the well-known Poisson equation of probability is rather instructive.

Some of the exponential laws, such as Boltzman's law of energy distribution, are derived from theoretical considerations; others, such as the absorption law for electromagnetic radiation by matter, are obtained experimentally. The general form of these exponential laws is as follows:

$$I = I_0 e^{-ax}, \tag{1}$$

in which I represents the magnitude of the quantity which depends upon the variable x, I_0 represents its initial value at $x = 0$, and a is a constant.

A few of the fundamental physical phenomena which are described by this equation are listed below:

The absorption of electromagnetic radiation by matter.
The distribution of molecular free paths in a gas.
The steady-state distribution of energy among gas molecules.
The decay of radioactive substances.
The decrease of current in an electric circuit.
Franklin's equation in acoustics for sound absorption.
The belt friction equation in mechanics.

This varied array of phenomena, all following the same exponential law, led to a search for a common principle among them which resulted in the discovery that they may all be derived from a simple and fundamental law of probability—that of Poisson.

Poisson's law,

$$p(n) = \frac{\alpha^n e^{-\alpha}}{n!}, \tag{2}$$

gives the probability for the occurrence of exactly n random events, when the expected number α is known. The basic assumptions contained in the law are that the events are distributed with respect to time, space or some other variable, purely by chance, or at random; that they are independent of each other, and that the total number of occurrences possible is large compared with the expected, or average, value α. It will be noted that the equation defines a distribution which is essentially discontinuous.

The derivation of the well-known expression for the distribution of molecular free paths, based on the above law expressed by equation (2), will next be given as an illustration.

MOLECULAR FREE PATHS.

First, imagine a set of points distributed at random along a line. Let the points symbolize collisions of a gas molecule with other molecules, and the distances between the points represent lengths of free paths. Let L be the mean of these free paths. Then $1/L$ will represent the average number of collisions per unit of length, and x/L the average number of collisions in a distance x. Here all of the assumptions implied in Poisson's law are ideally realized. Hence, the probability for exactly n collisions in a distance x may be found by substituting x/L for α in the equation (2). Next, letting n equal zero, the result,

$$p(0) = \frac{(x/L)^0 e^{-x/L}}{0!} = e^{-x/L}, \tag{3}$$

expresses the probability that there will be no collisions in a distance x. But this is nothing more than the probability that a molecule will have a free path equal to or greater than x. Therefore, out of I_0 molecules, the number having free paths equal to or greater than x is

$$I = p(0) I_0 = I_0 e^{-x/L}, \tag{4}$$

which is the familiar kinetic theory expression for the same thing.

RADIO-ACTIVE DECAY.

The decay of radio-active substances furnishes a good illustration of events randomly distributed with respect to time. In this case, let the points along the line (of the previous example) represent impulses, or causes, (whose nature is at present unknown) operating on the atom and tending to activate it in some way causing the emission of an α particle. All that need be known about them is that they arrive in a random manner, purely by chance. Let S be the mean time between these impulses. Then $1/S$ will be the average number of impulses per unit of time, and t/S will be the average number in t units of time. As before, we substitute t/S for α and 0 for n in Poisson's equation, which reduces simply to

$$p(0) = e^{-t/S},$$

an expression which represents the probability that there will be no impulses in the interval t, and hence that the atom will remain unactivated for a length of time equal to or greater that t. Then, out of a total of I_0 atoms, initially, the number remaining unchanged after time t will be

$$I = p(0)I_0 = I_0e^{-t/S},$$

which is just the experimentally determined law of radio-active decay in which $1/S = \lambda$ is the familiar "radio-active constant" of the substance.

ABSORPTION OF RADIATION BY MATTER.

As a final illustration, let us consider the absorption of homogeneous electromagnetic radiation by matter, attacking it from the corpuscular point of view. Our results then will also apply to the case of beta radiations. Consider a random distribution again representing atoms in space, with an average number N per unit volume. Next, imagine the path of a photon projected through the region, and for the sake of concreteness, assume that this path has an effective diameter λ and that the atoms also have an effective diameter δ. Then the average number of atoms per centimeter path of photon, L, will be $N\pi(\lambda + \delta)^2/4$; so that the mean number in a distance d will be Ld. Using Poisson's law as before, the chance

that there will be no collisions in a distance d will be

$$p(0) = \frac{(Ld)^0 e^{-Ld}}{0!} = e^{-Ld},$$

which represents the probability that a given photon will travel a distance equal to or greater than d without encountering an absorbing atom. Letting the intensity of radiation be proportional to the number of photons passing per cm.^{2} per second, the intensity of radiation at a distance d will be

$$I = p(0)I_0 = I_0 e^{-Ld},$$

where I_0 is the intensity at $d = 0$. But this again is the experimental law for the absorption of homogeneous radiation, where L is the familiar "coefficient of absorption," which according to our assumptions equals $N\pi(\lambda + \delta)^2/4$. If, then, we measure L experimentally we can set a limit to the quantity $(\lambda + \delta)$. For example, in the case of nitrogen, the mass absorption coefficient L/r was found to be 0.251 for 0.35 A.U. Thus,

$$N\pi(\lambda + \delta)^2/4r = 0.251,$$

whence

$$\frac{2.7 \times 10^{19}\pi(\lambda + \delta)^2}{4 \times 0.00125} = 0.251,$$

from which

$$(\lambda + \delta) = 3.86 \times 10^{-12} \text{ centimeters.}$$

This means that the effective diameter of photon and stopping entities together is much less than the diameter of the molecules themselves (3.5×10^{-8} cm. as determined from viscosity and other measurements). This, of course, is in accord with the view that the entities are the electrons within the atoms. If either λ or δ can be determined the other will be given by the above equation. The other laws listed can be deduced in an analogous manner.

The foregoing deduction of these laws, while perhaps furnishing no new knowledge of the *ultimate* processes, nevertheless seems highly suggestive. It has the advantage of bringing out explicitly the common principles underlying the processes, . . . randomness, or chance, and independence. Furthermore, the step represented by equation (4) is neither

permissible nor exact unless the number of entities involved, I_0, is very great. In the present case the order of magnitude of the numbers involved is that of Avogadro, . . . ten raised to the twenty-third power, so that the step is both permissible and exact. These tremendous numbers account for the apparent uniformity of these laws, . . . laws which are based fundamentally upon random processes of an essentially discontinuous nature. Here then is another example of large-scale order resting upon small-scale disorder. If it were possible to magnify the exponential curve sufficiently we would find it actually a "stepped" curve. Another possible value of the present development is in furnishing a physical picture of the process, a factor which has often in the past been suggestive of new experiments or hypotheses. It also allows a somewhat different interpretation of the constants encountered in the experimentally determined exponential laws, as for example in the third problem of absorption of electromagnetic radiations by matter.

Spores Ride High.—(U. S. Dept. of Agriculture.) Plant disease fungi are themselves a form of plant—but a type of very low order. A distinguishing characteristic of the lower forms of plant life is the production of spores rather than seeds. If a well developed plant disease fungus is viewed under a microscope one may see numerous spherical spore cases in which repose numberless tiny spores, fine as dust, lighter than a feather. When ripe, their confining envelope cracks open and the liberated multitude float away on the currents of air.

As part of the Agricultural Department's plan of service to the farmers, it has delegated one of its plant pathologists, F. C. MEIER, to hunt for these plant disease spores in the upper reaches of the atmosphere. Through the cooperation of the Department of National Defense airship and airplane have been placed at the investigator's disposal. Flying at heights of 18,000 feet Mr. Meier has gathered spores of fungus diseases which attack tomatoes, potatoes and fruit crops. Collection is accomplished by holding a nutrient-coated sterilized glass plate in the air a short time during flight. Back in the laboratory the spore-infested plate is placed in an incubator and the spores indentified after they develop.

A possible practical benefit of such spore-stalking and identification should result in timely warnings to farmers that plant diseases ordinarily non-prevalent in the neighborhood have been brought thither by some prevailing air current and the crops should be sprayed.

C.

Chemistry of the Vitamins.—IDA B. ROUTH (*Jour. Chem. Ed.*, 1933, x, 13–19) has published an excellent resumé of recent advances in this field. The precursor of fat-soluble A, the vitamin which prevents the disease of the eye known as xerophthalmia, is the hydrocarbon carotene $C_{40}H_{56}$. This complex compound is converted into the active vitamin by enzymes in the liver. Vitamin B_1 or F is water-soluble; it prevents beri beri in man; its empirical formula is $C_{12}H_{17}N_4OS$; the structure of the molecule is unknown. Two entirely different formulæ have been assigned to water-soluble C, the vitamin which prevents scurvy. Some research workers believe that this vitamin is the alkaloid narcotine, in which two methoxy groups have been converted into phenol groups by removal of their methyl radicals. Other investigators claim that this vitamin is a hexuronic acid. Synthetic vitamin D, which is fat-soluble and prevents rickets, is a metamer of ergosterol.

J. S. H.

DAVID RITTENHOUSE—PHYSICIST.[1]

BY

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Five weeks ago our community paid honor to the memory of David Rittenhouse upon his two hundredth birthday. On that occasion citizens of southeastern Pennsylvania joined with representatives of scientific and technical societies of national and international scope to recall the character and achievements of our distinguished citizen of a former century. There lived again in our thoughts Rittenhouse the schoolboy and the farm boy of Norriton township, Rittenhouse the maker of clocks and mathematical instruments, and of the famous orreries, Rittenhouse the surveyor of colonial boundaries and of public works, Rittenhouse the amateur astronomer whose observations of the transit of Venus made with instruments of his own construction commanded the attention of the scientific world, Rittenhouse the high official of the young state of Pennsylvania, and of the young United States, Rittenhouse the educator and the fellow and officer of learned societies, and Rittenhouse the neighbor and the citizen, "Rittenhouse the ingenious, the modest and the wise."

Yet, one phase of his many-sided career was barely touched upon during the bicentennial exercises. In fact, in the judgment of the writer, it has never been adequately told that Rittenhouse, throughout his life, was a keen student of Natural Philosophy and of physical problems.

David Rittenhouse was born in 1732, five years after the death of Sir Isaac Newton. Early in his career, while he was still living on the farm at Norriton, Rittenhouse read an English translation of the Principia. He developed into "a thorough and zealous disciple of the Newtonian School." Of Newton "he ever spoke with a species of respect bordering upon veneration."

[1] Read before the Physics Club of Philadelphia, May 13, 1932.

Certain incidents illustrate his devotion to Newtonian philosophy. On the twenty-fourth of February, 1775, in an address on Astronomy delivered before the American Philosophical Society, Rittenhouse referred to Newton as "the great master builder" who reared up the "whole splendid group of materials" collected by his predecessors "into due order and proportion."

Fifty years after the death of Newton there remained among educated men a few who rejected his philosophy and accepted in preference the ideas of Descartes. In the issue of The Pennsylvania Magazine for June 1776, we find Rittenhouse appearing in reply to "M. W." and "J. W.," two clergymen, who had contributed articles in adverse criticism of Newtonian ideas. Both had openly displayed preference for the Cartesian theories.

On October 8, 1767, while he was still living at Norriton, Rittenhouse sent to the *Pennsylvania Gazette* over the pen-name "A Mechanic" a solution of the problem "How far will the mutual attractions of the earth and a 200 pound ball near its surface displace each in a given time?" A previous contributor to the *Gazette* had raised this question in a discussion of the saying of Archimedes: "Give me a place to stand on, and I will move the Earth." His solution was wide of the mark. Rittenhouse gave the correct solution and in so doing demonstrated his mastery of Newton's laws of motion. He explained his contribution as prompted by "the justice due Archimedes, and the respect I bear for that truly great man's memory." [2]

The compressibility of water was a moot question among physicists until comparatively recent times. Cajori in his History of Physics says: [3]

"It was long believed that in liquids, sound waves, consisting of condensations and rarefactions, could not travel at all, for the reason that liquids appeared to be incompressible. The compressibility of water had been the subject of experimentation on the part of the Accademia del Cimento in Florence, sometime between 1657 and 1667. Hollow spheres

[2] William Barton's Memoirs of Rittenhouse, p. 581.

[3] Cajori, "A History of Physics," p. 280. *Phil. Trans.*, Vol. LII, part 2, p. 641.

of silver were filled with water, closed tight, and then disfigured by hammering. The water was forced through the pores of the metal. Apparently water is incompressible. Boyle believed that water was elastic, but could not establish his view by conclusive experiment. In 1762 John Canton demonstrated before the Royal Society that water is compressible, but his test received little attention."

The test did receive attention in Philadelphia—from Rev. Ebenezer Kinnersley, Rev. Thomas Barton, and David Rittenhouse. On March 27, 1767, Rittenhouse wrote to Rev. Barton, his brother-in-law, at Lancaster, Pennsylvania, concerning tests of the compressibility of water made before the Royal Society by Canton [3] and apparently repeated by Rev. Kinnersley. He concludes: [4] "Indeed I do not doubt the compressibility of water, although the above experiment does not much please me. If the particles of water were in actual contact, it would be difficult to conceive how any body could much exceed it in specific gravity; yet we find that gold does, more than eighteen times."

Both James Renwick and William Barton, biographers of Rittenhouse, refer to experiments on the compressibility of water performed by him. The writer of this paper has not been able to find records of these experiments.

It will be recalled that by trade Rittenhouse was a maker of high-grade clocks. Most of these clocks were made for household use. A few were precision timepieces for use in surveying and in astronomical observation. It followed that Rittenhouse had to deal with the problem of making pendulums which would swing with constant period. On November 7, 1794, he read before the American Philosophical Society a paper "On the Improvement of Timekeepers" [5] in which he described a device designed to compensate a pendulum for change of period arising from change in the density of the air.

The device consisted of an extra bob attached to the rod of the pendulum, above the axis of rotation. This extra bob was related to the usual bob in size, weight, and position in such a way that a change in density of the air gave rise to equal and opposite torques about the axis of rotation. An

[4] Barton's Memoirs, p. 155.

[5] *Transactions Amer. Philosophical Society*, Vol. 4.

experimental model was described and its performance in air and in water explained.

An astronomical clock made by Rittenhouse and used by him had an ingenious device for compensating the pendulum for expansion with rise of temperature. I quote from a description [6] of this clock by Robert Patterson Esq., an early director of the United States Mint. "In the Astronomical Clock made by Dr. Rittenhouse, and now in the Hall of the Philosophical Society, I do not know that there is anything peculiar except the pendulum; especially the apparatus for counteracting the effects of change of temperature."

"For this purpose there is fastened on the pendulum-rod (which is of iron or steel) a glass tube of about thirty-six inches long; bent in the middle into two parallel branches, at the distance of about an inch from each other; the bend being placed downwards, immediately above the bob of the pendulum. The tube is open at one end, and close at the other: the arm which is close at top is filled, within about two inches of the lower end or bend, with alcohol, and the rest of the tube, within about one half of an inch of the upper extremity or open end, with mercury; a few inches of the tube, at this extremity, being about twice the width of the rest of the tube. Now, when the heat of the air increases, it will expand the pendulum-rod; and would thus lower the center of oscillation, and cause the clock to go slower; but this effect is completely counteracted, by the expansion of the alcohol chiefly, and of the mercury in part; which equally raises the center of oscillation; and thus preserves an equable motion in all the variable temperatures of the atmosphere."

In pursuance of his efforts to make pendulums of constant period for his clocks Rittenhouse made a study of the effects of temperature and humidity upon the dimensions of wood. His paper "On the Expansion of Wood by Heat" [7] was sent as a letter to the American Philosophical Society on May 15, 1795.

He explains that pendulum rods had been made of wood because of a prevalent belief that wood does not change in dimensions with change of temperature. His own experience led him to question this belief. Accordingly he subjected

[6] Barton's Memoirs of Rittenhouse, p. 585.

[7] *Trans. Amer. Phil. Soc.*, Vol. 4, p. 29.

hickory wood to 250 degrees Fahrenheit in a sand bath and observed its expansion with a micrometer microscope. He found that "On the whole very dry wood expands with heat pretty regularly, though certainly in much less degree than any of the metals or even glass." Further experiments led him to conclude "that the expansion of wood in its length, will be irregular, corresponding partly to the warmth, and partly to the moisture of the atmosphere."

About 1782 Rittenhouse made and used a hygrometer of novel design. A description [8] of the instrument by Robert Patterson and David Rittenhouse Waters is quoted. "The essential part of this Hygrometer consists of two very thin strips of wood, about a foot long and half an inch broad, glued together, in such a manner that the grain or fibres of the one shall be at right angles with the other; so that when this compound strip was placed in an erect position, the grain of one of the pieces of wood would have a vertical, and that of the other an horizontal position. One end of this simply constructed instrument is to be made fast to a wall, or plane board, with the edge outward, and the other end is to be at liberty to move."

"Then, as moisture has little or no effect on the length of a piece of wood, or in the direction of its fibres, but a very sensible one on its breadth, or transverse direction, especially when thin, it follows, that on any increase in moisture in the air, this Hygrometer becomes bent into a curve, convex on the side of the transverse fibres; and vice versa. The degrees, from the greatest dryness to the greatest moisture, are to be marked on a curve drawn on the board or wall, described by the motion of the free end of the Hygrometer; and an index, attached to the moving end of it, will point out, on this graduated arch, the existing state of the atmosphere at the moment, in relation to its condition of moisture or dryness."

It is obvious that the indications of this instrument must have lagged far behind the instantaneous humidity of the atmosphere. It is of interest to compare this description with a principle proposed by Dr. Benjamin Franklin in a letter written from France in 1780 to Mr. Nairne, an instrument maker of London. This letter was read before the American

[8] Barton's Memoirs, p. 585.

Philosophical Society on January 28, 1786.[9] There is no evidence however that Rittenhouse had knowledge of Franklin's ideas. Rittenhouse's hygrometer was mounted in his observatory at Seventh and Arch Streets, Philadelphia.

Cajori states[10] that "the earliest thermometer depending on the expansion and contraction of metallic rods was invented about 1747 by Peter van Musschenbroek of Leyden." Whether Rittenhouse knew of this invention is not known to the writer. In any event about twenty years later, that is early in 1767, Rittenhouse "contrived and made an ingenious thermometer,[11] constructed on the principle of the expansion and contraction of metals, by heat and cold, respectively. This instrument had under glass, a face upon which was a graduated semi-circle; the degrees of heat and cold corresponded with those of Fahrenheit's thermometer; and these were also correspondently designated, by an index moving on the center of the arch." It is described as rugged, portable, and of pocket size. Several specimens were made. One was used for several years by Rev. Thomas Barton at Lancaster, Pennsylvania. It is to be regretted that no detailed description of the metallic element of this instrument exists, at least so far as the writer is aware.

In The Library of American Biography, James Renwick refers to Rittenhouse's thermometer in these words:[12] "Another valuable application of a correct knowledge of the relative expansions of solid bodies also occurred to Rittenhouse, and he carried this application into successful practice. In this he forestalled, in the career of discovery, Breguet, who, within the present century, has received no small praise for the reinvention of a forgotten instrument of Rittenhouse's. We refer to the metallic thermometer."

The claim that Rittenhouse anticipated Breguet has been made by other writers. The present writer for lack of information about the Rittenhouse thermometer is unable to pass upon the merits of the claim.

Early in life Rittenhouse began the study of optics, as the

[9] *Trans. Amer. Phil. Soc.*, Vol. 2.

[10] Cajori, "A History of Physics," p. 111.

[11] Barton's Memoirs, p. 159.

[12] The Library of American Biography, Vol. 7, p. 334.

following incident shows. Braddock's expedition against Fort Duquesne was cut to pieces near the fort in July 1755, and the frontier of Pennsylvania was left wide open to the Indians for three years. During this period Rittenhouse wrote from Norriton to his brother-in-law, Rev. Thomas Barton, then a missionary on the frontier in a district now included in Adams county, Pennsylvania, "I have not the health for a soldier and as I have no expectation of serving my country in that way, I am spending my time in the old trifling manner, and am so taken with optics, that I do not know whether, if the enemy should invade this part of the country, as Archimedes was slain while making geometrical figures on the sand, so I should die making a telescope."

We are told by his nephew, Professor B. S. Barton, that late in his life Rittenhouse seriously contemplated giving a course of public lectures on Optics.[13] The plan of the course was fully developed in his mind. For some reason the lectures were never given.

In a letter[14] read before the American Philosophical Society in November 1785 Rittenhouse describes an ingenious optical device designed as a "New Method of Placing a Meridian Mark." A newly erected building north of his observatory had made his meridian mark 1200 feet away invisible. Rittenhouse says, "I contrived several other methods of supplying its place, all of which were, on sufficient deliberation, rejected for the following. I fastened the object glass of a thirty six feet telescope, firmly, to the wall which supports the transit instrument, opposite to and as near as convenient to the object glass of the transit, when brought to a horizontal situation. In the focus of the thirty six feet object glass I screwed fast a piece of brass to a block of marble, supported by a brick pillar built on a good foundation, for this purpose, in my garden. On this piece of brass are several black concentric circles; the rest of the plate is silvered. . . . The circles are therefore distinctly seen through the transit, and being placed in the same meridian with the center of the thirty six feet glass, the innermost circle, about the size of a brevier serves for a meridian mark, to the center whereof the

[13] Barton's Memoirs, p. 603.

[14] *Trans. Amer. Phil. Soc.*, Vol. 2, p. 181.

cross hair of the transit may be nicely adjusted." It is pointed out in the letter that such a mark is free from parallax, is not sensibly affected by tremors in the air, and is capable of quick and convenient illumination at night.

In a postscript to this same letter Rittenhouse reveals that for some time he had been using spider threads for the cross hairs of short focus eye-pieces, instead of silk fibres. A spider thread he describes as "not one tenth of the size of the thread of the silkworm, and rounder and more evenly of a thickness."

In response to a request [15] from Francis Hopkinson that he account for phenomena seen when a distant light is viewed through a stretched silk handkerchief held before the eyes Rittenhouse describes an experiment in the "inflection of light" original with him which may be regarded as the prototype of the first experiment with the diffraction grating now performed by every student of elementary optics.

Parallel light from a slit was passed normally through a coarse plane grating of parallel hairs fastened upon a metal frame. Six orders of diffraction spectra were observed, and their deviations from the path of the original light were measured. It was found that the deviation of a color in the nth order was n times its deviation in the first order. This was done by Rittenhouse before Fresnel and Fraunhofer were born. The writer has commented upon this experiment at greater length upon a previous occasion and a review of it has since appeared abroad.[16]

Rittenhouse conceived of light in terms of Newton's corpuscles. Inflection he attributed to forces exerted by the hairs of his grating upon the corpuscles. Accordingly he drew no conclusions from his experiment as to wave-lengths of various colors. The concept of wave-length of light was foreign to his thinking.

An experimental investigation of an illusion described at length under the title Explanation of an Optical Deception [17] gives a convincing picture of Rittenhouse as a master of the scientific method.

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[15] *Trans. Amer. Phil. Soc.*, Vol. 2, p. 201.

[16] JOURNAL OF THE FRANKLIN INSTITUTE, July 1932. *Nature*, Oct. 1, 1932.

[17] *Trans. Amer. Phil. Soc.*, Vol. 2, p. 37.

Experiments in magnetism engaged David Rittenhouse and John Page of Williamsburg, Virginia, in a correspondence [18] which ran through the years 1779, 1780, and 1781. In closing the series of letters Rittenhouse set forth his views as to the nature of magnetism. He says: "I suppose then, that magnetical particles of matter are a necessary constituent part of the metal which we call iron, though they are probably but a small proportion of the whole mass. These magnetical particles I suppose have each a north and a south pole, and that they retain their polarity, however the metal may be fused or otherwise wrought. In a piece of iron which shews no signs of magnetism these magnetical particles lie irregularly with their poles pointing in all possible directions, they therefore mutually destroy each others' effects. By giving magnetism to a piece of iron we do nothing more than arrange these particles, and when this is done it depends on the temper and situation of the iron whether that arrangement shall continue, that is, whether the piece of metal shall remain for a long time magnetical or not."

"There is some power, whencesoever derived, diffused through every part of space which we have access to, which acts on these magnetical particles, impelling one of their poles in a certain direction with respect to the earth and the other pole in the opposite direction. The direction in which this power acts I take to be the same with that of the dipping needle." . . .

"Iron or soft steel receives magnetism more easily than hardened steel, but will not retain it; may not this be, because the magnetical particles are not so closely confined in soft as in hardened steel, and on that account more easily admit of arrangement or derangement."

These words were written by Rittenhouse in 1781. In this year was born S. D. Poisson [19] who assumed "that each molecule becomes magnetized when the field begins to act." Twenty-three years later (1804) was born Wilhelm Weber [19] who assumed "that the individual particles are permanently magnetic. . . ." "He advanced the view that in hard steel there was some kind of friction between the molecules, which

[18] *Trans. Amer. Phil. Soc.*, Vol. 2, pp. 173–181.

[19] Cajori, "History of Physics," p. 257.

prevented the molecules of magnetized steel from turning back into higgledy-piggledy positions."

Rittenhouse describes experiments showing effects of heat, contact, and mechanical blows upon magnetized bodies. All these effects are in conformity with his views as to the nature of magnetism. From these records it may be claimed that Rittenhouse entertained and expressed fundamental ideas as to the nature of magnetism which were elaborated by his successors, Poisson and Weber, and in recent times by J. A. Ewing.

In the heyday of Benjamin Franklin's scientific activity Philadelphia was a world-center in the study of electricity and lightning. It is then not surprising that we find David Rittenhouse giving attention to these fields. The summer of 1789 must have been attended by severe electrical storms in these parts. On June 7 of that year several houses in Philadelphia were struck by lightning, and on July 17 we find David Rittenhouse and Dr. John Jones jointly reporting observations on these houses to the American Philosophical Society.[20]

On August 17, 1789, the historic Leiper house on Crum Creek, Delaware County, was struck by lightning. The owner, Mr. Thomas Leiper, invited David Rittenhouse and Francis Hopkinson to investigate the effects of the stroke. The house was unusual in that it was equipped with two lightning rods. In their report [21] the investigators give a detailed description of the house and surroundings and of the effects of the lightning. They close the report by saying: "From our observations on the above case, as well as some others that have occurred, we would strongly recommend to those who put up pointed rods, that the lower end be sunk sufficiently deep to reach moist earth in the dryest seasons. And we submit it to those conversant with electrical philosophy, whether, when there are more rods than one to a building, it may not conduce much to its safety to form a good connection between the rods, and likewise between them and a copper water spout; carrying an iron or copper rod from the lower end of the spout a sufficient depth into the ground."

[20] *Trans. Amer. Phil. Soc.*, Vol. 3, p. 119.

[21] *Trans. Amer. Phil. Soc.*, Vol. 3, p. 122.

If one sentence be added to this recommendation to the effect that the network of conductors thus constructed shall enclose the building with a net of large mesh, there results a description of the best of twentieth century practice in the protection of buildings against lightning.

At some date after the year 1770, Rittenhouse, Rev. Ebenezer Kinnersley, and some other gentlemen joined in making a series of experiments upon the Gymnotus Electricus, or electric eel, with the object of testing the electrical nature of the shocks given by the fish. Tests were made for conduction, insulation, attraction and repulsion, and sparks. Comparisons were made of the sensations caused in the human body by the shocks from the fish with those produced by discharges of static electricity. A complete identity was not established. The experiments were published [22] several years after the death of Rittenhouse.

This work on the electric eel was apparently authorized by the American Philosophical Society at its meeting of July 30, 1773.[23] At this meeting Messrs. Kinnersley, I. Bartram, Rittenhouse, Hollingsworth and O. Biddle were authorized "to agree with the Owner of the Torpedo, on terms to make a Set of Experiments, with a view to determine the nature of the Shocks which it communicates—not exceeding £3 for that priviledge; they are requested to call in to their assistance any gentlemen they think proper."

Records of the weather and of celestial phenomena were kept by Rittenhouse from September 24, 1788 to June 22, 1796. He died four days after the latter date. The records were continued from July 4, 1796 to September 30, 1805, by other hands. These records are contained in two diaries. One of them is now in the possession of Professor M. J. Babb. The other is in the library of The American Philosophical Society.

[22] *Phila. Medical and Physical Journal*, Vol. 1, pp. 96 and 159.
[23] Minutes of the Amer. Phil. Soc.

New Dairy Products.—(U. S. D. A. Clip Sheet, No. 762.) The Bureau of Dairy Industry which is constantly engaged in the development of new dairy products recently held a "demonstration luncheon" at which the participants were served with samples of the newest products. In addition, the menu included foods that were improved in nutritive value by the addition of milk solids in one form or another.

Two types of cheese were used in the sandwiches. One was a Cheddar cheese made by a new method in which the cheese ripens in a special value-equipped container. The other was a Swiss cheese, made by an improved method of bacteria control. Also, there was Roquefort cheese made from cow's milk instead of sheep's milk as in France. Concentrated milk, held frozen for a week or more, was thawed and restored to its original volume by the addition of water. This possessed all the attractiveness of fresh milk.

Dry skim milk was used in the bread for the sandwiches. Milk sugar was substituted for a large part of the cane in making the chocolate creams. Caramel candy included a newly discovered antioxidant which reduces the deterioration of the butter it contains.

C.

Some Interesting Figures.—The U. S. Department of the Interior issues the statement that the amount of electricity produced for public use in the United States in 1931 was almost 92 billion kilowatt-hours. Of this amount 67 per cent. was produced by fuels, the remainder by water power. Of the total amount of fuel-generated electricity 82 per cent. was produced by coal, 4 per cent. by oil, 14 per cent. by gas and less than 1 per cent. by wood. The amount of natural gas consumed in generating electricity in 1931 was 2 to 6 times the amount in 1926.

The best fuel rates in 1931 were about as follows: Coal, 1.00 pound per kilowatt-hour; oil, 430 kilowatt-hours per barrel; and gas, 11.4 cubic feet per kilowatt-hour. One ton of coal is equivalent to 3.9 barrels of oil or to 21,800 cubic feet of gas.

C.

GRID AND PLATE CURRENTS IN A GRID-CONTROLLED MERCURY VAPOR TUBE.

BY

A. C. SELETZKY[1] and S. T. SHEVKI.[2]

SYNOPSIS.

An oscillographic and quantitative investigation of the grid and plate currents of a grid-controlled mercury vapor tube, operating in an a.c. circuit, as functions of grid voltage and resistance, plate voltage and phase displacement between grid and plate voltages.

It is shown that the direction of grid current depends not only upon the instantaneous polarity of the grid but also upon the magnitude of the grid voltage and upon the plate current. The grid current wave may consist of positive loops only, of positive and negative loops of varying areas or of equal areas, and of negative loops only. The various factors affecting the form of grid current wave are considered in detail.

Inverse plate current occurs whenever the grid current is concurrent with the negative half-cycle of the plate voltage. The minimum value of inverse plate current occurs when there is no grid current coincident with the negative half-cycle of the plate voltage. It is caused by the lag of deionization of the mercury vapor furnishing a small amount of ionization when the plate voltage becomes instantaneously negative. With a constant average grid current the magnitude of the inverse plate current varies approximately sinusoidally with phase displacement between grid and plate voltages.

I. INTRODUCTION.

The increasing use of grid-controlled mercury vapor tubes for regulation, control and rectification makes desirable a study of certain characteristics of these valves, which, judging from the literature available, have not as yet received the attention they deserve. The behavior of plate and grid currents, especially the latter, may in some instances inhibit the proper functioning of the tube and cause it to fail to play its proper role in the circuit. As far as the authors know, the only investigator who has published his findings

[1] Instructor, Electrical Engineering Department, Case School of Applied Science.

[2] Graduate Student, Electrical Engineering Department, Case School of Applied Science.

on the subject is Nottingham,[3] who studied the grid and plate currents of thyratrons chiefly under conditions prior to discharge. He found, as might be expected, that before the cathode-to-anode discharge takes place, the tube behaved as a gaseous triode. It became evident from preliminary experiments that some interesting studies were possible by investigating the plate and grid currents under various conditions of discharge.

A grid-controlled mercury vapor tube is essentially a triode operating in an atmosphere of mercury vapor. Detailed accounts of the principles of operation have appeared in numerous papers.[4] When the grid is strongly negative, relative to the cathode, none of the electrons emitted by the cathode will be able to overcome the negative gradient of the grid and pass to the anode; the plate current will be zero. As the grid becomes less and less negative, electrons having the higher velocities will be able to reach the anode; by doing so they will produce a small amount of ionization of the mercury vapor by collision. The positive ions which result from this ionization will be attracted to the grid and when the grid attains the "critical" voltage, the degree of ionization will be such that a positive ion sheath envelopes the grid, which effectively robs the grid of its control and a discharge takes place between the cathode and anode, provided of course, that the anode is positive with respect to the cathode. Once the discharge occurs, no further variation of the grid voltage will have any appreciable effect on the plate current flowing. If the tube be operated in a d.c. circuit, the discharge can only be interrupted by removing the plate potential. Thus in a d.c. circuit the grid can only initiate the plate current but cannot control it.

If alternating potentials be applied to the grid and plate, the plate current will begin to flow at the point on the positive half-cycle of plate voltage at which the grid voltage reaches the critical voltage. The position of this point in the cycle can be controlled by varying the phase displacement between the anode and grid voltages. This makes possible the regu-

[3] JOURNAL OF THE FRANKLIN INSTITUTE, 212, 271 (1931).

[4] A. Hull, *Trans. A. I. E. E.*, 47, 753–765 (1928). A. Hull, *Gen. Elec. Rev.*, 32, 213–223 and 370–399 (1929).

lation of the average value of plate current, which is determined by the interval under the positive loop of plate voltage, extending from the point where the plate voltage passes through zero, going from positive to negative, to the point where the grid attains critical voltage.

II. PROCEDURE.

The tube used for this investigation was a General Electric F G-29, air cooled thyratron, intended for use as a controlled rectifier. The cathode was of the uni-potential coated variety, the heater of which drew 12 amperes a.c. from a special filament transformer. The thyratron was designed for a maximum forward and inverse potential of 3500 volts and a maximum average plate current of 12.5 amperes.

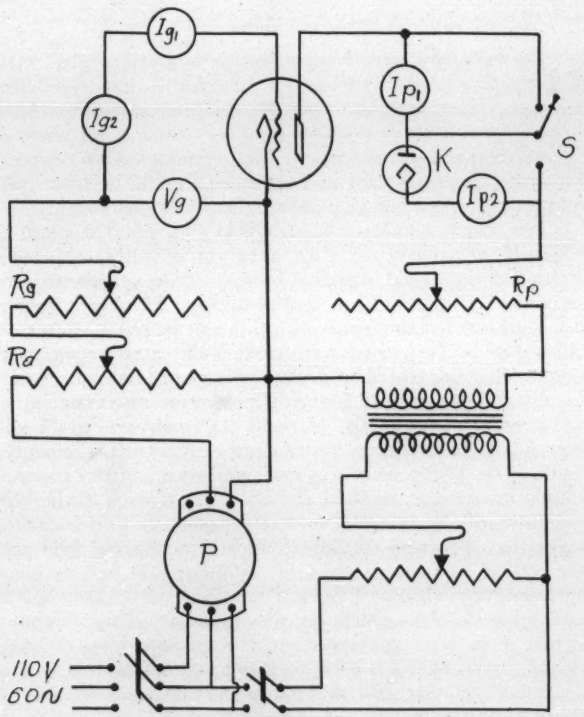
The circuit employed is shown in Fig. 1. The plate of the tube was energized with a 110/1100 volt transformer. Voltage for the grid, variable in magnitude and phase, was obtained by means of a potential divider, *Rd*, which in turn was connected to one phase of a three phase phase-shifter, *P*. All the tests performed were carried out at 60 cycles and unless otherwise stated, at a plate voltage of 1100 volts, r.m.s.

Ig_1 and Ip_1 were d'Arsonval meters for measurement of the average values of the grid and plate currents, which will be referred to as *Ig* av. and *Ip* respectively. The effective value of the grid current was measured with a heater-thermocouple instrument, marked Ig_2; the r.m.s. values of the grid currents will be referred to as *Ig* r.m.s. A dynamometer voltmeter, Vg_1, was connected directly across the grid and the cathode to measure the grid voltages. The inverse plate currents were measured by a d'Arsonval micro-ammeter or milliammeter, Ip_2, whichever was necessary. By throwing switch *S* to the upper position, the positive loop of plate current was blocked with a kenotron, marked *K*. The resistances of the grid and plate circuits were varied by variable resistances, *Rg* and *Rp*, respectively.

In the oscillograms which are to be presented, the authors thought it would be more expedient to give the average and effective values of grid currents in lieu of placing current scales on the oscillograph traces themselves. Using a three element oscillograph two photographs of each condition were

taken in order to include the four variables, Vg, Ig, Vp and Ip. In the figures all four quantities have been shown together by inking the wave of Vp on the oscillograms which had the other three values.

FIG. 1.



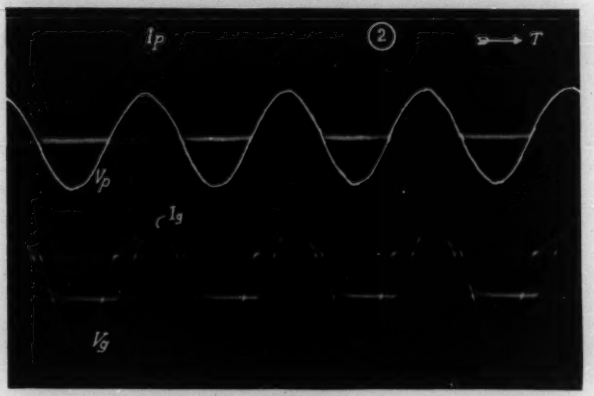
General setup.

III. GRID VOLTAGE IN PHASE WITH PLATE VOLTAGE.

A typical picture of the grid current when the grid voltage is in phase with the plate voltage is given in Fig. 2. The magnitude of the grid voltage was 30 volts and the average

value of the grid current was 175 milliamperes with a grid resistance of 100 ohms. It will be noticed that the grid current follows the shape which would be expected from ordinary rectifier action, with the exception that it lags somewhat behind the grid voltage. This is partly due to the natural reactance of the grid circuit and also to the fact that the grid must attain a certain positive voltage before it can repel the positive ions which approach it by virtue of their velocities. The grid current persists for a short interval after the grid and plate become negative. Part of this positive

FIG. 2.

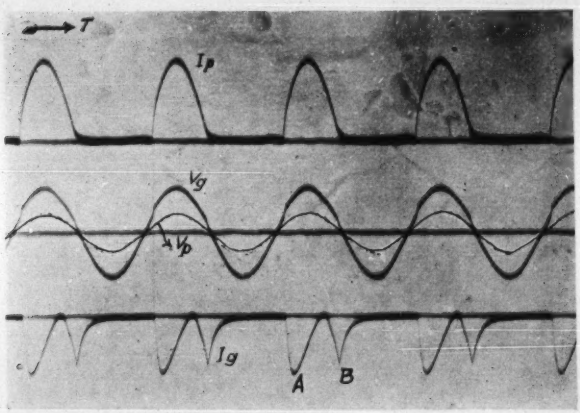


Vg and Vp in phase.
Vg = 30 volts, r.m.s.
Ig av. = 175 milliamperes.
Rg = 100 ohms.
Vp = 1100 volts, r.m.s.
Ip av. = 4 amperes.

tail is accounted for by the deionization time of the mercury vapor and the remainder by electrons coming from the cathode which have sufficient kinetic energy to overcome the negative voltage gradient of the grid. The plate current, the average value of which is 4 amperes, consists of complete positive loops whenever the plate voltage is positive, since the grid voltage is in phase with the plate voltage.

The direction of current in the grid circuit depends not only upon whether the grid is positive or negative but also upon the magnitude of the grid potential. If the voltage of the grid be low, some of the electrons emitted from the cathode may enter the grid, even though it be negative; likewise if the grid be at a low positive potential, some positive ions will be able to enter the grid. This accounts for the varied shapes which the grid current may assume at low voltages. In Fig. 3, for instance, two negative peaks of

FIG. 3.



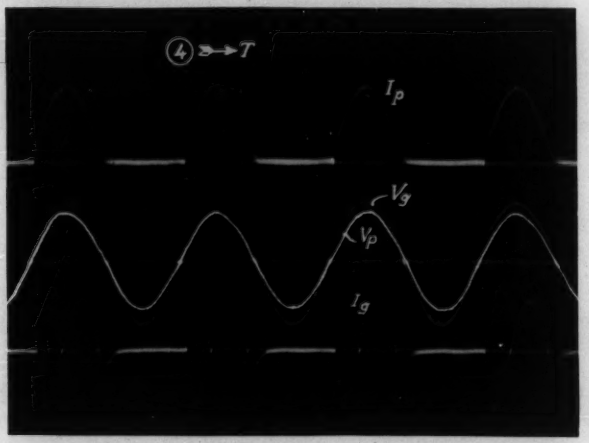
Vg and *Vp* in phase.
Vg = 5 volts, r.m.s.
Ig av. = − 2 milliamperes.
Rg = 100 ohms.
Vp = 1100 volts, r.m.s.
Ip av. = 1.2 amperes.

grid current resulted, when the voltage of the grid was reduced to 5 volts. The grid resistance was the same as before, 100 ohms, and the average grid current was − 2 milliamperes. Here the grid current lies entirely below the zero axis. Some of the positive ions, generated by the ionization due to plate current, overcome the positive gradient of the grid and thereby engender a negative grid current. This type of

current has been described by Langmuir and Smith [5] in their study of currents taken up by collectors in mercury arc.

The negative grid current increases with increase in plate current until the rate of increase is reduced to zero by the increase of positive grid voltage. This is peak "A" in the oscillogram. As the grid voltage increases to its maximum value in the cycle, it repels more and more of the positive ions until the negative grid current is reduced to zero. At

FIG. 4.



Vg and Vp in phase.
Vg = 6 volts, r.m.s.
Ig av. = 0.
Ig r.m.s. = 3 milliamperes.
Rg = 100 ohms.
Vp = 1100 volts, r.m.s.
Ip av. = 1.2 amperes.

this point in the cycle the positive grid voltage begins to decrease and hence the negative grid current grows once more. At this part of the cycle, however, the plate current is also decreasing and hence the supply of positive ions is decreasing. This explains the second peak "B" in the grid current curve.

[5] *General Electric Review*, Vol. XXVII, pp. 449 and 538 (1924).

Although the positive grid voltage is decreasing, the supply of positive ions is waning at a more rapid rate, with a net result of decrease in negative grid current. In view of this oscillogram it would be expected that if the grid were operated at a slightly higher voltage, the curve of grid current should first go negative and then rise to a positive value.

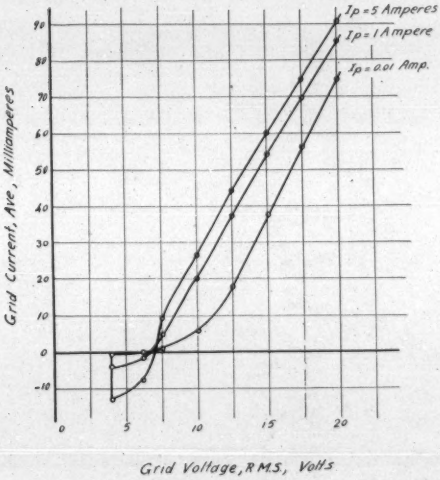
An increase of only one volt in the grid voltage modifies the shape of the grid current wave considerably. In Fig. 4 is shown the grid current for a grid voltage of 6 volts. The plate current was maintained at the same value as in the preceding case, 2 amperes, average. The initial loop of grid current is negative for the same reason as before. The voltage of the grid however, increases to a sufficiently high value in its cycle to repel enough positive ions and attract enough electrons to render the grid current positive. The increase in positive grid current is stopped by the fall in positive grid voltage. This decrease allows more positive ions to enter, thereby producing a small negative loop of grid current. The alternating voltage of 6 volts in this case produced a positive loop of grid current just equal in area to the sum of the areas of the two negative loops, so that *Ig* av. was zero. If the voltage of the grid be made higher, the grid becomes able to repel all of the positive ions and receive only electrons, which is the condition represented by Fig. 2.

When the grid voltage is in phase with the plate voltage, the grid current may assume a variety of shapes depending upon the magnitude of the grid voltage. When the grid voltage is sufficiently high, electrons are attracted to the grid and positive ions repelled, resulting in positive loops of grid current; as the grid voltage is lowered, positive ions are able to enter the grid when it is positive and a negative loop of grid current makes its appearance; finally with very low grid voltages, enough positive ions enter the grid when it is positive to render the grid current completely negative.

The variation of average grid current with grid voltage, *Vg* and *Vp* in phase, is given in Fig. 5, for three values of plate current, 5 and 1 amperes and 10 milliamperes. From 0 to 3.75 volts the grid currents were too small to show on the plot. The behavior of the grid current in this region has

been described by Nottingham.[6] The cathode-to-anode discharge took place at 3.75 volts. At this point the ionization due to plate current flowing, furnished positive ions of sufficient velocity to enter the grid and make the areas of the negative loops exceed the area of the positive loop, as was the case in Fig. 3. The average value of the negative grid current, for a given Vg, depends upon the degree of ionization, i.e. upon the plate current. Hence the 5 ampere

FIG. 5.



Vg and Vp in phase; Vp = 1100 volts, Rg = 100 ohms.

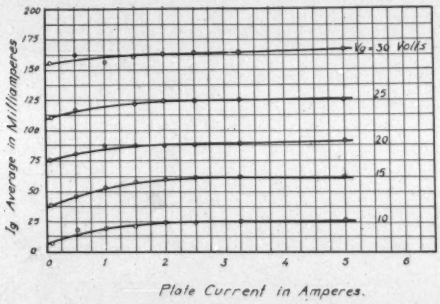
curve has the greatest negative value of Ig av. and the 10 milliampere curve has the smallest negative value of Ig av. As the grid voltage is increased, the positive loop of Ig increases and the negative loops decrease, causing the curves of Ig to attain a negative maximum and return to zero. All three curves cross the zero axis in the Vg interval, 6.5–7

[6] Loc. cit., p. 295.

volts. This is the condition where the positive loop of Ig is equal to the negative loop as shown in Fig. 4. The positive loop of Ig also increases with the ionization. Hence above the zero axis of Ig, the three curves lie above each other in the order of magnitude of their corresponding plate currents, because the positive loop of Ig increases with Ip as well as with Vg and the negative loops finally disappear (see Fig. 2). Thus the curves of Ig cross as they intersect the zero axis of Ig and reverse their order.

To bring out more clearly the influence of the plate current upon the average grid current, Ig av. has been plotted

FIG. 6.



Vg and Vp in phase; Vp = 1100 volts, Rg = 100 ohms.

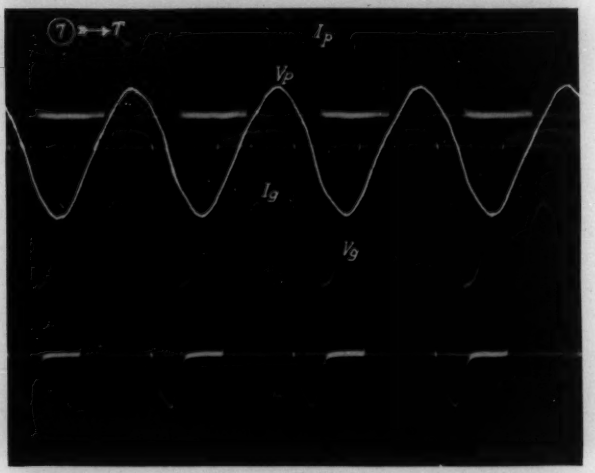
against Ip in Fig. 6 for grid voltages of 10–30 volts in 5 volt steps. As would be expected from Fig. 5, the grid currents increase with Ip at a decreasing rate and finally attain a saturation value which is independent of further increase of Ip.

IV. GRID VOLTAGE LEADING PLATE VOLTAGE.

In Fig. 7 the grid voltage is shown leading the plate voltage by 90°. The grid voltage was 40 volts. The grid current starts when the grid becomes positive, rises to a maximum and then falls to zero with the grid voltage. When the grid goes to negative values, the tube is still discharging and hence still generating positive ions. These positive ions

enter the negative grid forming a negative loop of grid current, which increases with the instantaneous value of the grid voltage, until the plate current is reduced to zero, when the source of positive ions disappears. At this point the negative grid current falls rapidly back to the zero axis and remains at zero until Vg becomes positive again in the following cycle. The average value of grid current in this case was 275 milliamperes. The first half of the positive loop of grid current current occurs before the tube discharges, whereas the total

FIG. 7.

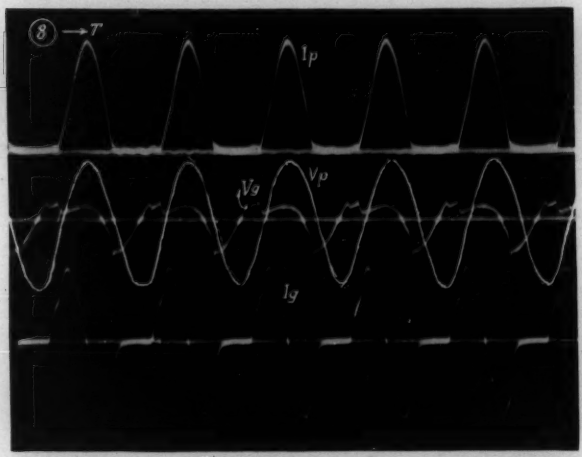


Vg leads Vp by 90°.
Vg = 40 volts, r.m.s.
Ig av. = 275 milliamperes.
Ig r.m.s. = 600 milliamperes.
Rg = 100 ohms.
Vp = 1100 volts, r.m.s.
Ip av. = 4 amperes.

negative loop of grid current occurs while the plate current is flowing. From this it would be expected that with decrease in Vg the negative loop would grow faster than the positive loop.

In the oscillogram shown in Fig. 7, when Vg was 40 volts, the average value of Ig was 275 milliamperes, showing the excess in area of the positive loop of Ig over the negative loop. In Fig. 8, the voltage of the grid has been reduced to 10 volts, at which value the negative portion of Ig decreased and became equal to the positive portion, making the average value of Ig zero, the effective value, however being 90 milliamperes.

FIG. 8.

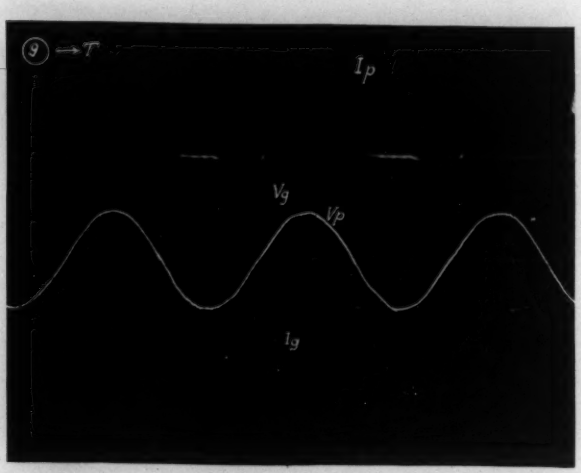


Vg leads Vp by 90°.
Vg = 10 volts, r.m.s.
Ig av. = 0.
Ig r.m.s. = 90 milliamperes.
Rg = 100 ohms.
Vp = 1100 volts.
Ip av. = 4.7 amperes.

When the grid voltage leads the plate voltage by 90°, a portion of the grid current loop occurs when the plate voltage is negative. The electrons travelling from the cathode to the grid ionize some of the mercury vapor and thereby furnish a source of positive ions. The plate being negative, during this interval of the cycle, it is natural to expect a small but distinct loop of negative plate current. This is

not evident in Figs. 7 or 8 because the magnitude of the plate current in each case was 4.7 amperes average, and the negative loop was too small to be observed on so coarse a scale. However, if Ip be reduced to 17 milliamperes, the negative portion of the plate current becomes plainly visible as is shown in Fig. 9. The variation of the magnitude of the negative plate current loop will be considered later. It is interesting to note the effect of a decreased plate current upon the negative loop of grid current in this oscillogram.

FIG. 9.



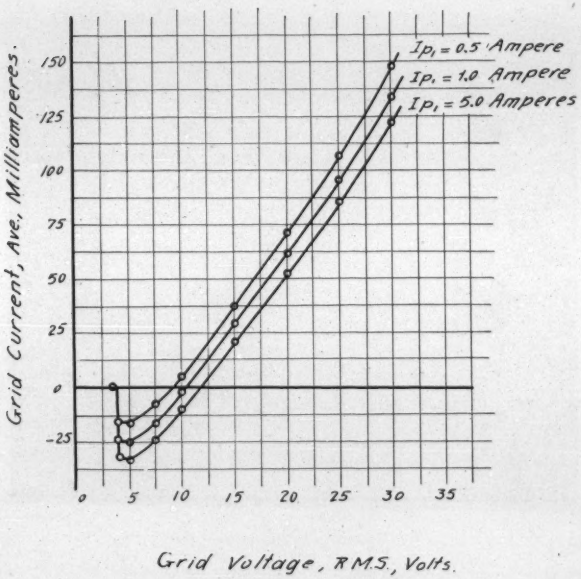
Vg leads Vp by 90°.
Vg = 62 volts, r.m.s.
Ig av. = 1.0 ampere.
Rg = 50 ohms.
Vp = 1100 volts, r.m.s.
Ip av. = 17 milliamperes.

Although the voltage of the grid was increased to 62 volts in this case, there is no negative loop of grid current present. The positive loop of Ig consists of electron emission current and its attendant ionization of the mercury vapor, which is independent of plate current; during the negative half-cycle of Vg, the positive ions were few in number because Ip was

only 17 milliamperes and the voltage of the grid had a sufficiently high value to repel them, with the result that the negative loop was entirely absent.

The variation of average grid current with grid voltage, with Vg leading Vp by 90° is given in Fig. 10. These curves are plotted for plate currents of 5, 1 and 0.5 amperes. The shapes of the curves are similar to those obtained with Vg in

FIG. 10.

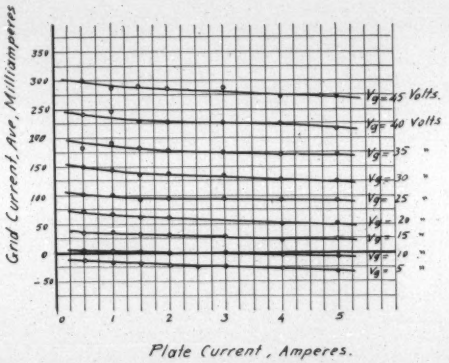


Vg leads Vp by 90°; Vp = 1100 volts, Rg = 100 ohms.

phase with Vp with the exception that the curves do not cross each other and reverse their order as they intersect the zero axis of Ig (see Fig. 5). From 0 to 3.75 volts the values of the grid currents were too small to plot, as in the preceding case (Fig. 5). At 3.75 volts, the tube discharged and the

grid currents became negative, the negative values, for a fixed Vg, increasing with the plate current. This is due to the negative loop of Ig increasing with the increase in ionization afforded by increase in Ip. As Vg increases the curves attain their negative maxima and return to the zero axis, in the interval between 9–12 volts Vg. This is the condition represented in Fig. 8 where the area of the negative loop of Ig is equal to the area of the positive loop. Above the zero axis of Ig the curves for the lower values of Ip assume higher positions, i.e. for a fixed Vg, the average value of grid current

FIG. 11.



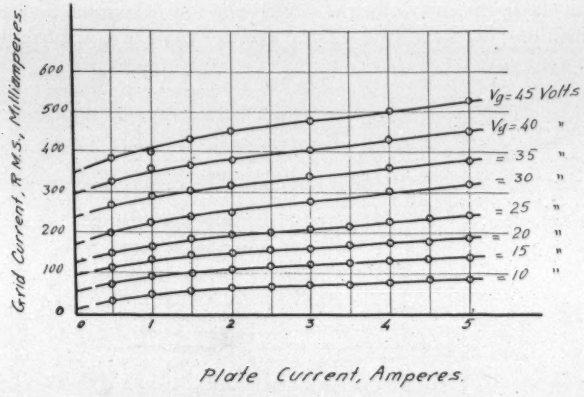
Vg leads Vp by 90°; Vp = 1100 volts, Rg = 100 ohms.

decreased with plate current. Referring to the oscillograms in Figs. 7, 8 and 9, the loops of negative grid current increase with the plate current. On the other hand a large portion of the positive grid current occurs before the tube discharges. The result of this is, that with increase in plate current for a fixed Vg, the negative portion of Ig grows more rapidly than the positive portion and the average value of Ig decreases with increase in plate current. For this reason the curves do not reverse their order as they pass the zero axis of Ig.

The change of average grid current with plate current is graphed in Fig. 11 for grid voltages of 5 to 45 volts in 5 volt

intervals. The decrease of Ig av. is clearly evident and is seen to be approximately linear. From what has been said it would also be expected that the effective value of the grid current under the same conditions should increase with the plate current, since the negative loop of Ig increases with the plate current. Figure 12 shows this to be the case.

FIG. 12.



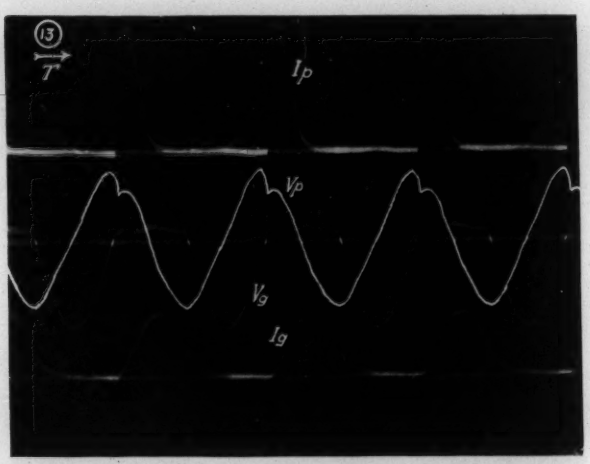
Vg leads Vp by 90°; Vp = 1100 volts, Rg = 100 ohms.

V. GRID VOLTAGE LAGGING PLATE VOLTAGE.

The behavior of the grid current, when Vg lags Vp by 90° is shown in the next two oscillograms, Figs. 13 and 14. In Fig. 13, the grid was maintained at 30 volts. During the negative loop of grid voltage no plate current is present, because no positive ions are available and the grid current is zero. When the grid becomes positive, a positive grid current begins to flow which increases to a maximum value and then tapers off to zero after the grid voltage has become zero. The discharge has ceased since the plate voltage has become negative; there is no source of positive ions for the negative grid and accordingly the grid current continues at zero until the grid becomes positive in the next cycle.

If the grid voltage be reduced to a considerably lower value as compared with Fig. 13, the positive loop of grid current will be found to shift its position from the second quarter-cycle (counting from the instant when the plate voltage becomes positive) to the first quarter-cycle. This condition is presented in Fig. 14 where the voltage on the grid was reduced to 5 volts. Comparing Figs. 13 and 14,

FIG. 13.

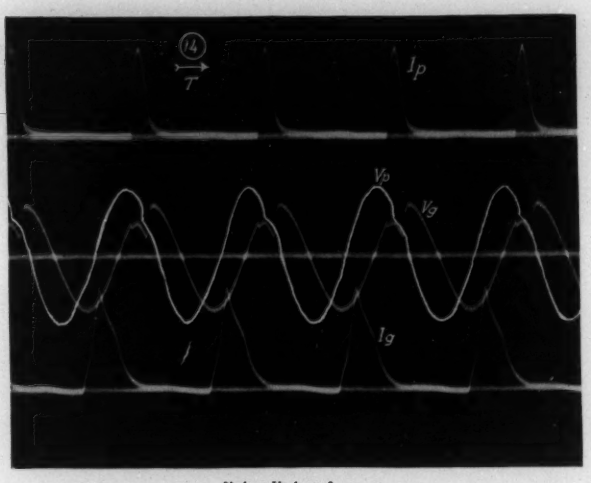


Vg lags Vp by 90°.
Vg = 30 volts, r.m.s.
Ig av. = 165 milliamperes.
Ig r.m.s. = 220 milliamperes.
Rg = 100 ohms.
Vp = 1100 volts, r.m.s.
Ip av. = 1.5 amperes.

it is apparent that the positive loop of grid current has shifted from the quarter-cycle during which the tube discharges, to the quarter-cycle of positive plate voltage during which there is no discharge. In Fig. 14 although the voltage of the grid is low, no electrons enter the grid by virtue of their velocities during the fourth quarter-cycle when the grid is negative on account of the negative potential of the plate. During the

first quarter cycle, however, the plate voltage is positive and electrons coming from the cathode are able to impinge upon the grid, although the grid is at a negative potential with respect to the cathode. Thus a positive loop of grid current is formed during the first quarter cycle. The total current produced by electron emission from the cathode entering the grid is small compared with the ionization available for

FIG. 14.



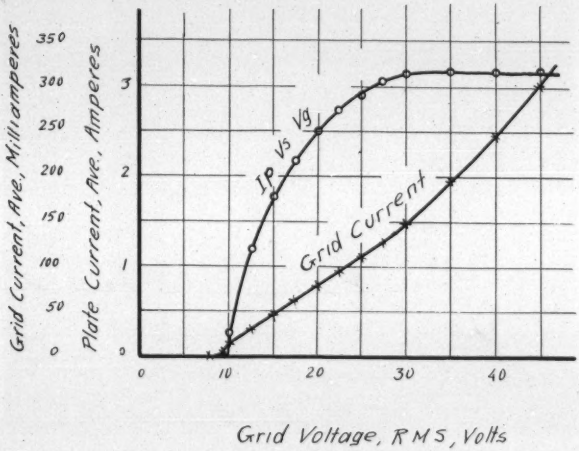
Vg lags *Vp* by 90°.
Vg = 6 volts, r.m.s.
Ig av. = 6 milliamperes.
Rg = 100 ohms.
Vp = 1100 volts, r.m.s.
Ip av. = 1.2 amperes.

production of grid currents when the tube is discharging. Accordingly the magnitude of the positive loop of grid current with *Vg* equal to 5 volts is small compared to the positive loop of grid current with *Vg* equal to 30 volts, the average grid currents in the two cases being 5 and 165 milliamperes respectively.

Referring to Fig. 14 again, when the grid voltage becomes

positive and discharge begins, the resultant ionization produced positive ions of sufficient velocity to enter the grid, although the grid is at a low positive potential and is receiving electrons from the filament. The net result is to reduce the grid current to zero and it continues at this value until the plate voltage becomes positive in the following cycle. If the voltage of the grid were lowered still further, the grid current in the second quarter cycle would not only be reduced to

FIG. 15.



Vg lags Vp by 90°; Vp = 1100 volts, Rg = 100 Ω.

zero, but depressed to a negative value by the positive ions generated by the plate current.

An examination of the oscillograms, especially the last two, will show that the tube studied had a positive critical voltage. With this condition present and Vg lagging Vp, the average plate current increased with increase in grid voltage, because Vg intersects the critical voltage curve earlier in the cycle as it is increased. This effect is shown in Fig. 15 where Vg lags Vp by 90°. The greater the value of Vg, the

shorter will be the time interval between $Vp = 0$ and the point where Vg intersects the critical grid voltage curve. Thus in Fig. 15, the average value of the plate current increases rapidly with grid voltage, finally reaching a constant value of 3.2 amperes when Vg is approximately 30 volts, which represents the maximum area under the positive loop of plate voltage in which plate current can flow with Vg lagging Vp by 90°. The increase of average grid current is shown on the same graph. It increases at an approximately linear rate until the grid voltage is 30 volts, after which the rate of increase continues more rapidly.

VI. INVERSE PLATE CURRENT.

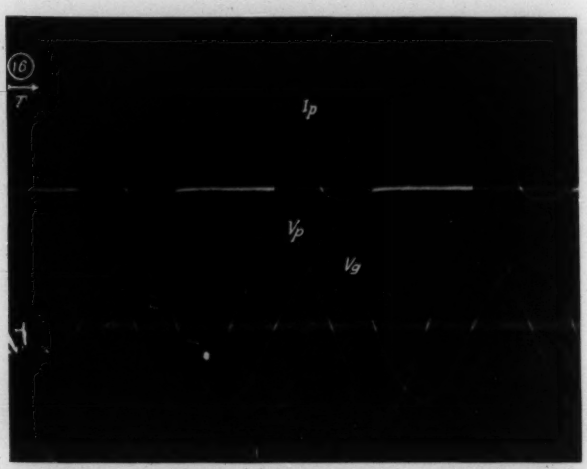
Referring to Figs. 7, 8 and 9, which pertain to grid voltages leading the plate voltages, it is apparent that the initial portion of the positive grid current loop occurred when the plate voltage was negative. The reverse is true when the grid voltage lags the plate voltage, as seen in Figs. 13 and 14. In this case, during the interval when the plate voltage changes from positive to negative, there is a loop of positive grid current, i.e. a source of positive ions; hence the plate current should have a negative loop. This negative loop of plate current may be seen in Fig. 16 where the average value of Ip was reduced to 16.5 milliamperes by increasing the plate circuit resistance and thereby making the magnitude of the negative loop comparable to that of the positive loop.

When there is a phase displacement of 175° between the plate and grid voltages, a positive loop of grid current is present during the entire interval when the plate is negative. Under this condition, therefore, a full loop of inverse plate current is to be expected. This is shown by Fig. 17 where the plate current was reduced to an average value of 13.0 milliamperes to make the negative loop proportionately larger.

From the oscillograms it is seen that the magnitude of the inverse plate current varies with the amount of grid current present when the plate voltage is negative. When the potential of the grid is sufficiently high to prevent electrons from impinging upon the grid when it is negative and likewise to prevent positive ions from entering the grid when it is positive, the grid current follows the grid voltage with a

certain lag. From this it follows that with a constant average grid current, maintained by adjustment of grid voltage, the variation of inverse plate current with phase displacement between grid and plate voltages should be approximately sinusoidal. In Fig. 18 are plotted values of negative plate current against angular displacement between grid and plate voltages for three constant values of average

FIG. 16.

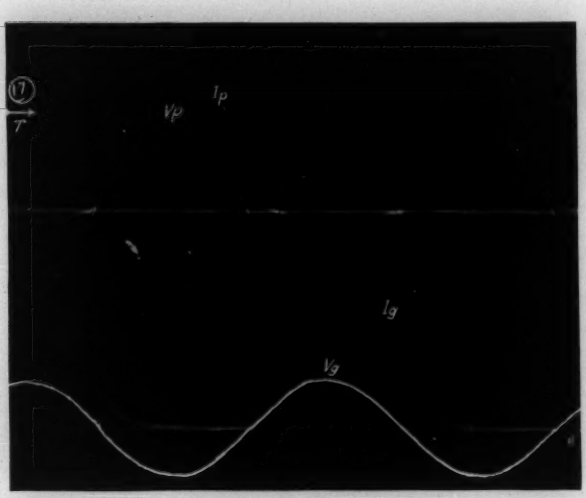


Vg lags *Vp* by 90°.
Vg = 60 volts, r.m.s.
Ig av. = 950 milliamperes.
Rg = 50 ohms.
Vp = 1100 volts, r.m.s.
Ip av. = 16.5 milliamperes.

grid current, 0.2, 0.75 and 1.5 amperes. These curves follow quite closely the form, $A + B \cos(\theta - \alpha)$, where θ is the angular displacement between Vg and Vp, α is the angular displacement between Vg and Ig and A and B are constants. Sinusoidal variations computed on the basis of maximum values of the observed currents coincide with the experimental curves obtained, except for a short section of the curve for

Ig av. = 0.2 ampere, where the portion of the computed curve which deviates is shown with a broken line. These curves were taken by throwing switch S, in Fig. 1, to the upper position, thereby blocking the positive loops of plate current with the kenotron and reading the average values of inverse current on milliammeter Ip_2. The plate voltage was maintained at 1100 volts r.m.s. and the plate circuit resistance

FIG. 17.



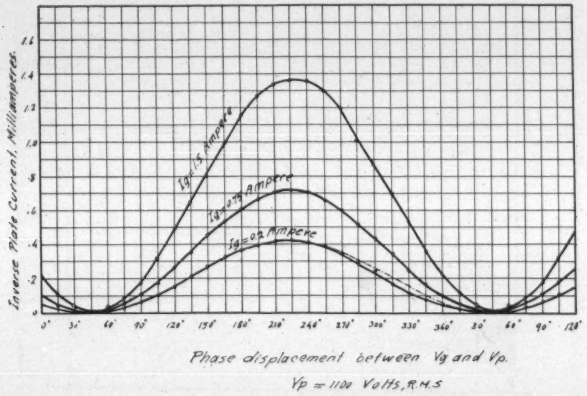
Vg leads Vp by 175°.
Vg = 60 volts, r.m.s.
Ig av. = 790 milliamperes.
Rg = 50 ohms.
Vp = 1100 volts, r.m.s.
Ip av. = 17 milliamperes.

when the inverse plate current was flowing, was the resistance of a KM-1 kenotron.

The grid current lags the grid voltage by approximately 40°. From this it would be expected that the maximum value of inverse plate current should occur when the positive loop of grid current coincides with the negative loop of plate

voltage, that is, at 180° + 40°. This is seen to be the case in Fig. 16. In the same way the minimum value of inverse plate current is shifted from the 0° point by the same angular displacement. There is no null value of inverse plate current due to the fact that when the positive loop of grid current is contained wholly within the positive loop of plate voltage, the plate becomes negative before deionization is complete; hence there is a small source of positive ions which yields a

FIG. 18.



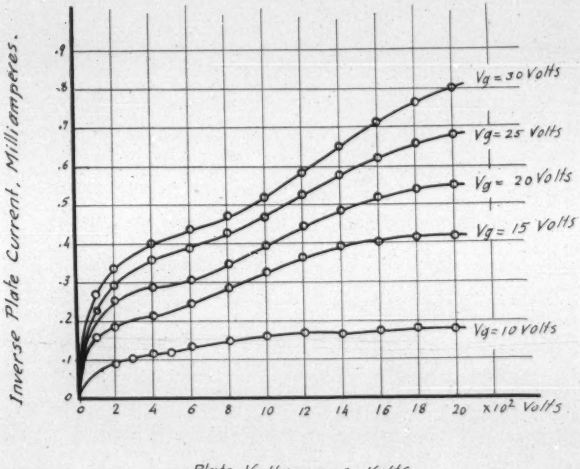
minimum but not zero value of negative plate current at that point. These minimum values for the 1.5, 0.75 and 0.2 amperes of *Ig* curves in Fig. 18 are 0.012, 0.005 and 0.003 milliamperes, respectively.

Thus, no matter what the phase displacement between the grid and plate voltages be, an inverse plate current is always present. Its minimum value is determined by the quantity of positive ions remaining, due to lag in deionization, when the plate potential reverses; its maximum value is determined by the magnitude of grid current which is present when the plate voltage is negative.

The behavior of the inverse plate current with *Vp* and

Vg 180° out of phase is given in Fig. 19 as a function of the plate voltage. With this phase displacement no cathode-to-anode discharge took place. Five curves are graphed for a range of grid voltages between 10 and 30 volts r.m.s.; the plate voltage was varied from 100 to 2000 volts r.m.s. The grid current in this case is made up of positive loops, formed by attraction of electrons from the cathode and this grid current creates a certain amount of ionization of the mercury

FIG. 19.



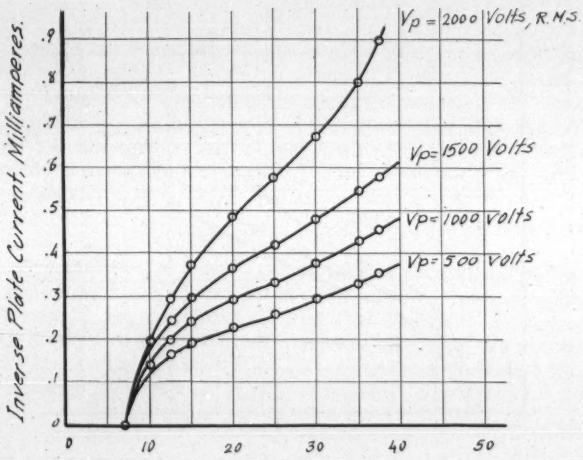
Vg and Vp 180° out of phase; Rg = 120 ohms.

vapor. With the phase displacement between Vp and Vg of 180° the loops of grid current are concurrent with the negative half cycles of the plate voltage giving rise to inverse plate currents which increase with Vg. The curves for Vg of 10, 15 and 20 volts exhibit saturation at Vp = 2000 volts. This indicates that all of the ionization present has been utilized for the formation of negative plate current. On the other hand with Vg at 25 and 30 volts, the greater degree of

ionization produced by the increased grid currents at these voltages was sufficient to require a voltage of greater than 2000 volts to obtain saturation of inverse plate current, as the two upper curves show. The behavior of the inverse plate current in this regard is very similar to the plate current-plate voltage characteristic of an ordinary triode operating in vacuum.

The observations indicated in Fig. 19 are replotted in

FIG. 20.

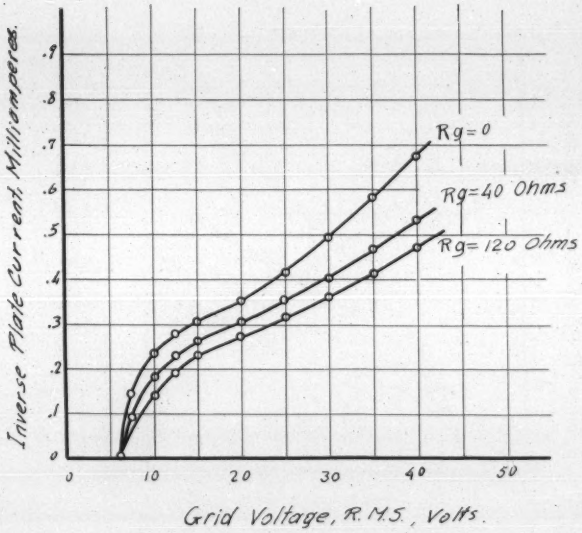


Vg and Vp 180° out of phase; Rg = 120 Ω.

Fig. 20 in order to present the inverse plate current as a function of the grid voltage. It was not economical to carry out the measurements for grid voltages much higher than 40 volts, with the grid resistances used, on account of the excessive grid currents which would flow and endanger the lead into the grid element. Below a grid voltage of 6 volts, the magnitude of the inverse plate current was too small to

show on the plot. The curves of inverse plate current increase rapidly from zero value, those drawn for the higher plate voltages being uppermost since plate current increases with plate voltage. It is interesting to observe that each curve presents a flex point, which occurs at higher values of Vg as Vp increases. For instance with $Vp = 500$ volts, the

FIG. 21.



Vg and Vp 180° out of phase, Vp = 1100 volts, r.m.s.

point of inflection occurs at approximately 20 volts; with $Vp = 2000$ volts the point of inflection occurs at 30 volts. This can be explained by considering the grid current flowing, which as has already been shown, furnishes the ionization for inverse plate current. When the grid is instantaneously positive it draws electrons from the cathode. These electrons, accelerated by the instantaneously positive grid, produce ionization by collision in the mercury vapor, as a result of

which the positive ions are able to neutralize the electron space charge and allow the grid current increase at a more rapid rate with grid voltage. This process does not continue indefinitely because of the resistance drop in the grid circuit. While the grid voltage is positive the plate voltage is negative (180° phase displacement); consequently as the plate voltage increases, a higher grid voltage will be required to produce neutralization of the electron space charge, which is indicated by the flex points of the curves of inverse plate current occurring at higher grid voltages as the plate voltage increases.

Since the magnitude of the grid current depends upon the grid circuit resistance, the inverse plate current should decrease as the resistance of the grid circuit increases. This is shown in Fig. 21, where the values of inverse plate current have been plotted against grid voltage for 0, 40 and 120 ohms resistance in the grid circuit. The phase displacement between the plate and grid voltages was 180° so that no cathode-to-anode discharge was present. The curves are of the same type as in Fig. 20, except that all of them are drawn for the same plate voltage of 1100 volts, r.m.s. and varying grid circuit resistances.

Two tubes of the same type were studied and only slight variations of magnitude in the phenomena described were observed. On account of the fact that the number of tubes was limited to two, the characteristics presented are not set forth as average characteristics but merely as typical of this particular type of grid-controlled mercury vapor tube.

VII. CONCLUSIONS.

1. The instantaneous direction of current flow in the grid circuit of a grid-controlled mercury vapor tube depends not only upon the instantaneous polarity of the grid with respect to the cathode, but also upon the magnitude of the effective grid potential and upon the plate current.

2. The grid current may consist of positive loops only, of positive and negative loops of varying areas or equal areas, and of negative loops only, depending upon the following factors:

a. The magnitude of the effective grid potential which determines whether or not the grid is able to repel positive

ions when it is instantaneously positive, and electrons when it is instantaneously negative.

b. The magnitude of the plate current which determines the degree of ionization present.

3. A d'Arsonval meter cannot be used in the grid circuit to determine the value of grid current, since the grid current wave generally has both positive and negative loops and in the extreme case where these are equal, such a meter would indicate zero current, although there may be an alternating current of considerable amount present.

4. When the grid voltage lags the plate voltage, the positions of the positive and negative loops of grid current may be transposed by merely varying the grid voltage.

5. An inverse plate current of the order of milliamperes is always present when grid current is concurrent with the negative half cycle of plate voltage. When the grid current during the negative half cycle of plate voltage is zero, the lag of deionization of the mercury vapor allows some ionization to be present when the plate voltage changes to negative, thereby yielding a minimum but not zero value of inverse plate current.

6. With constant average grid current, the inverse plate current varies approximately sinusoidally with the angular displacement between grid and plate voltages.

7. The formation of the positive ion sheath which envelopes the grid and causes cathode-to-anode discharge, is inhibited at low alternating grid voltages by electrons having sufficient kinetic energy to enter the grid when it is at an instantaneous negative potential. For consistent operation, the grid voltage employed to initiate discharge should be several times the critical voltage of the tube.

In closing, the authors wish to express their thanks to Professor G. H. Mills, who furnished the tubes used in this investigation.

CELEBRATION OF THE FRANKLIN INSTITUTE OF THE COMPLETION OF FIFTY YEARS OF VALUABLE SERVICES BY ALFRED RIGLING, LIBRARIAN AND ASSISTANT SECRETARY, 1883–1933.

Remarks by the President of the Institute, Mr. Nathan Hayward:

ALFRED RIGLING.

This is the fiftieth anniversary of Alfred Rigling's joining the staff of The Franklin Institute. He joined on February 13, 1883. I have not found exactly what position he had but as he was fourteen and a half years of age, assume he was library assistant. In 1887, when nineteen years old, he was made librarian of the Institute. At that time there were some eighteen thousand volumes on the shelves, and he has been in charge of this library ever since and has watched and largely guided its growth from the small eighteen thousand volume library to the present hundred and thirty thousand volume library.

I am not going to attempt to describe this collection of books and pamphlets but want to hit one or two high spots. It is rated as the best patent library in the United States, outside of Washington and New York. It has a very full record of patents not only of the United States but the foreign countries as well, including among others Germany, Austria, Switzerland, Japan and Great Britain and her important colonies.

One of the most important parts of the library is its very full set of bound copies of technical periodicals covering the full period of each respective series—something over a thousand such sets. These periodicals are so complete and so well arranged that people have found that they are able to get information from them better here than from almost anywhere else. They are referred to not only by Philadelphians and other nearby citizens but are constantly being consulted by those from other cities. A recent request which has been spoken of before is the case of the Congressman in Washington

who was unable to get what he wanted in the National Library but upon consulting us received the information within an hour or so.

It has been Mr. Rigling who has made this library what it is today and we are setting aside this day to do him honor, both as a record of our admiration of his work and of our affection for his personality.

I call upon the Secretary—

Presentation of Mr. Rigling for election to Honorary Membership in The Franklin Institute by the Secretary, Dr. Howard McClenahan:

With the whole-hearted approval of the Board of Managers, I have the honor to present for election to honorary membership in The Franklin Institute, Alfred Rigling, Librarian and Assistant Secretary of The Institute—

> "in recognition of a half century of helpful and intelligent service, during which long term of duty well done, he has been a pillar of strength to the Institute, a source of comfort to the discouraged and of knowledge to the ignorant, a librarian amazingly informed concerning his library, and a kindly gentleman skillful and eager in friendly service to his fellow-men."

King Solomon wrote

> "Seest thou a man diligent in his business? He shall stand before kings; he shall not stand before mean men."

Alfred Rigling has stood before the kings of the world of Science, and has aided in the advancement of the Kingdom of Knowledge.

The President announced that Mr. Rigling, whom we had hoped to have with us in order that we might pay honor to him publicly for his valuable services, was unfortunately ill and unable to be present. He stated that it was a case of "Hamlet without Hamlet" but that Mr. Rigling would be represented by Hamlet's ghost. The Secretary of the Institute then read the paper prepared by Mr. Rigling entitled—

REMINISCENCES OF FIFTY YEARS, 1883–1933.

I became a member of the Institute's staff nine years and a week after the celebration of its fiftieth anniversary, which

occurred on February 6, 1874 in old Musical Fund Hall. During that same year the Institute held its Twenty-seventh Exhibition of American Manufactures—on the site of the Wanamaker Store—the most successful one held up to that time. The management and membership were still proud of those two achievements in one year, and the funds which were accumulated as a result of that great exhibition had given new life to the Institute. The several officers and many committees were, however, already at work on the preliminaries for the International Electrical Exhibition to be held in September of the following year (1884). These activities with the routine work were sufficient to keep things going at a rather rapid rate.

I must remind you that in those days horse-drawn street cars were still the most rapid transit, the automobile had not made its appearance, electric street lighting was less than two years old. The telephone was already in use but there was none in this building. The typewriter was beginning to make its way rapidly, but the curly-headed stenographer had not become a part of the personnel until about 1890. Up to that time each officer conducted his own correspondence by hand, without even a fountain pen. This building was not wired for electric light until early in the fall of 1885.

In April 1883, William Barnett LeVan, a mechanical engineer, for twelve years a member of the Board of Managers, and for twenty-eight years active on the Committee on Science and the Arts, read a paper entitled "Sixty Miles an Hour on Present Road-beds." The speaker claimed that this average speed could readily be maintained upon existing road-beds of our railways. About a year later Mr. LeVan again addressed the meeting; his topic at that time was "New York to Chicago in Seventeen Hours." Both papers created much interest and there were many doubting Thomases. We now travel to Chicago in seventeen hours on the Broadway Ltd., leaving New York at 5 o'clock in the afternoon and arriving in Chicago at 10 o'clock the next morning. William Dennis Marks, Whitney Professor of Dynamical Engineering in the University of Pennsylvania, a noted engineer and an active member of the Institute, in his work "The Relative Proportions of the Steam-Engine," second edition, published in

1884, the manuscript of which was probably ready for publication sometime during the previous year, made the following statement:

"If we take 5000 pounds per square inch as the safe tensile strength of the steel tire of a locomotive, we find its lineal speed to be limited to about 2½ miles per minute, or 150 miles per hour, and it only remains for our engineers to provide boiler-capacity and road-bed adapted to such speeds in order that they may be realized by a properly constructed locomotive. This speed would shorten the time between New York and Philadelphia (90 miles) to 36 minutes." This feat has not yet been accomplished, but there is hope.

During my first year there was presented to one of the monthly meetings the report of the Committee on Prevention of Fires in Theatres. This most interesting document marked a new era in theatre construction. It included a resumé of theatre fires throughout the world, with some indications of the causes of such fires, their frequency, and proper directions to make such buildings more safe. The report concluded with thirty-eight recommendations some of which were:

Wider corridors
Exits to be marked
All doors to open outward
No long row of seats
Water tank above auditorium
Stage to be divided from auditorium by fire-proof drop-curtain
Firemen to be on duty in all theatres
Fireworks not to be used unless scenery, gauzes and woodwork have been made fire-proof
Work-shops and paint lofts to be outside of building.

Fifty years ago there was a group of daily visitors to the Institute. They were not so much after knowledge as they were after personal contacts. They had frequent conferences and looked upon the Institute as a sort of club house. The Actuary of that time, Mr. David S. Holman, found it possible occasionally to spend some time with these regulars. One day he had a discussion on astronomy with one of them. This particular gentleman had considerable knowledge on

this fascinating subject and was a sort of salesman for a portable planetarium, which was called the Heliotellus. A specimen of this instrument is still in the possession of the Institute and will form a part of the Astronomical Section of the new Museum. The discussion about stars grew interesting and the question of their names seemed to be of the greatest importance. Mr. Holman inquired why the stars were given certain names and whether the names had any relation to their form or appearance. The astronomer replied "No, they do not look any more like their names than you look like yours." Whereupon Mr. Holman jumped to his feet and remarked "Do you mean to say that I do not look like a 'whole man'?"

Another member of this daily dozen was a gentleman who belonged to one of the oldest families in Philadelphia. His education was not neglected, but he had no special training in science. He became a member of the Institute just prior to the exhibition of 1874 and continued throughout his entire life, over thirty years. His waking hours were spent in the Institute and he was a faithful attendant at all lectures and meetings. His income was sufficient to enable him to cultivate hobbies and he had many throughout his life. At one time he decided to see how many books he could read in a given time. He became a subscriber to a local circulating library. He borrowed one book at a time, brought it here and read it. As soon as he finished one he would go to the library and get another; some days he would read three. He continued this program for six months, and in that time he had read three hundred and sixty-five novels. He claimed to be able to keep the plots of all these stories separate in his mind.

In 1883 there existed here a Phonographic Section, composed of young people, most of them in their early twenties. Isaac Pitman shorthand was taught under the direction of the Actuary of the Institute. This was one of the first stenographic schools in the city, it began in 1876. These enthusiasts met frequently for instruction and practice. The more expert were occasionally permitted to report some of the Institute lectures and for those less rapid one of the students, a young man with oratorical ability and inclinations,

acted as speaker. In the class were two young women who became quite expert. One accepted a position as instructor in shorthand at Girard College, and the other became Secretary to the President and instructor in proof-reading at Drexel Institute. The young man who acted as speaker on many occasions became a clergyman in a nearby parish. His father had been a member of the Institute before him, and he became a member on reaching his majority and continued so throughout his life. One of the students, later a noted physician, used his shorthand extensively in his practice. His records of cases were all in shorthand and I hope he never had any difficulty in reading them.

The International Electrical Exhibition was held in the fall of 1884 in the old Pennsylvania Railroad Station at 32d and Market Streets and a building especially erected on the Northwest Corner of 32d Street and Lancaster Avenue, the two buildings being connected by a bridge. This, the first International Electrical Exhibition, was the most brilliant exhibition ever given by the Institute. A unique feature of this exhibition was the electric fountain, which created no great surprise, but it was the forerunner by nearly a dozen years, of the much discussed fountain at Willow Grove, which has been admired by so many thousands during the past thirty odd years. Incidentally, I might remind you that both these fountains had a common ancestor—an illuminated colored fountain shown by Prof. Henry Morton, first resident Secretary of the Institute, in a lecture on "Sunlight and Moonlight," delivered in the American Academy of Music, in 1868. Two hundred and eighty-two thousand paid admissions were recorded at this exhibition, sixteen thousand six hundred fifty-seven pupils from ninety-seven schools were taken through the exhibition by seven hundred and forty teachers. From a financial standpoint this was the most successful undertaking ever held under the auspices of the Institute.

In its desire to help others a series of tests were undertaken after the close of the exhibition. These covered efficiency and duration tests of incandescent electric lamps, tests of dynamo electric machines, electro-dental apparatus, electric signalling and recording apparatus, electric telegraphs,

batteries, etc. At the end of the year the financial balance, which could have been applied to so many purposes, was gone. There was satisfaction, however, in the knowledge that another infant industry had received encouragement.

During the continuance of the exhibition meetings of noted electricians were held. By special act of the Congress of the United States there was created the United States Electrical Commission, which was empowered to invite native and foreign scientists to participate in the National Conference of Electricians. This conference was held in September 1884 and was really international in character. Sixteen representatives came from abroad, including, Lord Kelvin, Sir James Dewar, Sir Oliver J. Lodge, etc. The American conferees numbered seventy-seven, including, Prof. Cleveland Abbe, Prof. Alexander Graham Bell, Bradley A. Fiske, U.S.N., Prof. S. P. Langley, H. A. Rowland, etc. A series of pamphlets, twenty-five in all, was issued under the title "Primer of Electricity," copyrighted in 1884 by Prof. E. J. Houston. They contained elementary information on all subjects relating to electricity: arc lights, incandescent lights, dynamo-electric machines, voltaic batteries, electric currents, etc. Eighty thousand of these pamphlets were sold during the period of the exhibition at two cents each. Before the close of the exhibition some wag issued the

> Primer of Electricity Number 0,
> Copied wrong by Prof. How's It Done?
>
> This Primer contains an immense amount
> of useless misinformation condensed in
> wonderful and unavailable form.

How many copies of this particular issue were published I do not know, I have only seen two of them in recent years.

Only one permanent feature remains of that great exhibition, that is the Memorial Library of the International Electrical Exhibition. This collection of books on electrical subjects was made by a committee on bibliography, consisting of three of the active exhibition promoters. Appeals were sent to authors and publishers of electrical books throughout the world and as a result of this committee's

work a library of three thousand titles was on display during the continuance of the exhibition. A sum of money was also collected which became a permanent fund the income of which is used for the purchase of electrical reference books. This was the second book fund, the first being that of Mrs. Bloomfield H. Moore, in memory of her husband, which she established in 1878.

One of the most remarkable demonstrations in the engineering field was given in this hall on December 28, 1884, when Elmer L. Corthell, noted civil engineer, spoke on the Tehuantepec ship railway. This was in the days before the Panama Canal. Mr. Corthell gave a review of the needs and requirements of transportation by land and sea, and included a historical resumé of the several plans for a ship railway across the Isthmus. The idea for this ship transport originated in the mind of Captain James B. Eads, whose plans were being placed before the Institute by Mr. Corthell. The impressive feature of this meeting was the working model to scale, from the plans of the full-sized works. This model was beautifully made, and occupied all the floor space across this lecture room. Every detail was included, pontoon and railway cradle, turn-table, elevators, etc. It required twenty-four hours to fill the tanks which represented the oceans on both sides of the Isthmus.

In the fall of the following year the Institute held its Twenty-ninth exhibition in the buildings used during the previous year for the Electrical Exhibition. This was the Novelties Exhibition. It included novelties in all branches of manufacture and industries, but from a financial standpoint it was not a success. The leading feature of this exhibition was the frozen fountain, installed in the center of the main building by the DelaVergne Refrigerating Machine Company, and replacing the illuminated fountain of the previous exhibition. At this exhibition were shown for the first time specimens of the modern half-tone printing blocks which are now used almost exclusively for purposes of illustration in newspapers, books and magazines. They were the invention of Mr. Frederick E. Ives, these many years a member of the Institute. He also exhibited at that time a three-color half-tone process print. Mr. Ives is still intensely interested

in color photography. His first contribution to the Journal of the Institute appeared in May 1885 and the issue for August 1932 contains his latest article on the subject. This was the last exhibition held under the auspices of the Institute. The plan of holding exhibitions periodically was abandoned because it was difficult to find suitable buildings for such purposes.

All great artists seem to have had the idea that lightning traveled in a zigzag course, and if you will examine storm pictures by West, Turner, Doré and others, you will always find the same kind of lightning, a wide band with two or more sharp angles, tapering to a point when it is about to strike. Mr. W. N. Jennings, a member of the Institute for fifty-one years, began making photographs of lightning in 1882. Because of the slow plates and lenses he was unable to obtain a good photograph until August 5, 1885. This photograph was shown as a lantern slide in this hall for the first time at the monthly meeting of the Institute on the third Wednesday of September 1885. Upon examining this photograph you will note that the path of lightning is sinuous, not zigzag. Hundreds of photographs taken since that time confirm this statement. Mr. Jennings became interested in photography as a hobby more than fifty years ago and later made it his profession. He has been pushing the button and doing the rest all these years.

The Institute's School of Drawing, which began in October 1824 and continued without interruption until April 1923, was in a most flourishing condition during the last score of years of the last century. The Director of the School had spent the greater part of his life in the drafting room of one of the large industrial establishments, and was familiar with drawing-room practice in all its branches. His course of instruction was intended for young men and women who were already engaged in engineering organizations and who felt the need for further information on drawing-room practice. The attendance during that period was so great that for several seasons it was necessary to conduct classes four nights in each week instead of the usual two.

Within a year or two after taking charge of the School, the Director found that a text-book would simplify matters

in the class-room to a great extent. He soon completed his plans and published for distribution, in his classes only, a small work with printed text and blue-print illustrations. These volumes became so popular that he soon found it necessary to print and publish the entire work, including the illustrations. Three volumes were prepared, one for junior students, another for intermediates and a third for the seniors. These were the first text-books on the subject of mechanical drawing, and while they were intended for the students in our own classes, orders for them were received from all the important technical schools throughout the country, the sales running as high as one thousand copies a month.

The Military Academy at West Point introduced the books into its drawing classes and ordered a model, to scale, of the engine, which is illustrated in the senior volume of the series. The model was built under the author's supervision and became a part of the West Point instruction. There are now a great many text-books on drawing, and it will be found that the greater number follow the general plan outlined in the volumes used in the Institute's School, fifty years ago.

Instruction in other branches of technology was given at different times. In 1825 and 1826 mathematical classes were in session. After a lapse of years this subject was again taught, beginning in 1898. Two years later the scope of these classes was enlarged and analytical and theoretical mechanics, strength of materials, machine design were added to the curriculum, this then becoming the Department of Machine Design. These classes were continued for twenty-five years.

In 1899 a Department of Naval Architecture and Marine Engineering was established. This had the support of all the ship-building establishments in and around Philadelphia. It was the first time that these subjects were given separately. Prior to this time they had always been a part of an engineering course in college or university. This school was in flourishing condition until the decline of the shipbuilding industry some years ago.

In 1923 the Committee on Instruction was of the opinion that the instruction given here was available in several other institutions and some branches of study were a part of the public school curricula. Recommendations were there-

fore transmitted to the Board of Managers that the several departments of the school be suspended. These recommendations were adopted and after ninety-nine years all school activities were discontinued. Unfortunately, what had not been taken into account was the contact which had been made through the students of the several departments of instruction. All relatives, friends and acquaintances of students and graduates were loyal admirers of the Institute. Many of them had no other reasons for taking an interest in the Institute, the other activities meant nothing to them. With the discontinuance of the schools this great host of admirers and supporters no longer felt obliged to be loyal to the old Institute, or take any interest in it.

Our Alumni Association, which for fifteen years was an additional stimulus, is gradually diminishing in numbers for the want of new accessions to its membership. We have therefore lost an army of faithful followers. It is hoped that the new technical museum, the details of which are now being planned, may in a degree be a sufficient attraction to restore to us the admiration and coöperation of the friends of the many thousands of matriculates of the school during the ninety-nine years of its existence.

During these many years I have had the confidences of a number of our good friends. On rare occasions the confidence has been only an inducement for support for some invention or enterprise, which seldom progressed beyond the experimental stage.

I am glad to say, however, that I have many pleasant recollections from contacts with those who have come and gone during the past half century. I am reminded especially of two engineers whose friendship I was privileged to gain. One noted throughout the country, the other less noted, but no less able. These two gentlemen, unknown to each other, had conceived a plan for a combination book-stack and reading-room. These plans were described to me by each gentleman, in confidence of course, and up to this moment I have not disclosed them. I feel that now I am violating no confidence in making these ideas public. One of the gentlemen died in New York City in 1899, the other died about fifteen years ago in this city in abject poverty.

In a few words their plan consists of a fire-proof building for a stack, say, ten stories high, each stack story being seven feet high approximately. Above this ten-story stack is to be a reading-room of a slightly larger floor area, also seventy feet high. This upper portion of the building could have windows on all sides, and if wanted, a sky-light. The stack sections are to be eighteen feet in length, two-sided, but instead of being constructed in one piece as is customary, they are to be in separate lengths of about six feet each. Each of these ten-story stack sections is to be mounted on a plunger elevator. The tops of the stacks, when in normal position, are the floor of the reading room. This room can be used for meetings, exhibitions, banquets or any other purpose.

When the library is open the attendants are to be stationed somewhere near the entrance. The reading tables are to be along one side of the room. A student wishing to consult books on any particular subject makes inquiry of the attendant as to the location of such works in the stack. He then takes a chair and seats himself in what is really the aisle of the book-stack and by pushing a button the particular section of the stack begins to move upward until the subject in which he is interested is before him, when the lift is halted. At the end of the day when the library is closed all of the book-stacks are of course lowered into the vault and the reading-room is again ready for other uses. Some of you will undoubtedly see objections to this method of storing books, but it is novel if nothing else, and I think it is interesting to know that two minds, independent of each other, conceived the identical idea.

Our good friend Dr. Henry Leffmann, of blessed memory, said on several occasions that institutions are like human beings—they grow up, flourish, prosper, grow ill—sometimes unto death—but in most cases recover and regain their strength. The struggles of those earnest, loyal and enthusiastic gentlemen who founded the Institute should never be forgotten. It is the one outstanding trait through years of disappointments and failures. For several decades they found it difficult to make ends meet. Whenever they had a little more money than seemed necessary, some call came to them for help and they were ready and willing to undertake

experiments and investigations of any kind for the public good, and in this way the treasurer was frequently able to report a deficit at the end of the year. This occurred over and over again.

During my career, up to the turn of the century, the Institute suffered continually from pernicious anemia of the check book, reports to the contrary notwithstanding. I remember in my own case receiving on one occasion pay for five months in one installment. The struggle continued until after the beginning of the present century, and while conditions are very much more favorable now, especially as far as the library is concerned, we must bear in mind that our enlarged program for future work does not yet leave us entirely free from anxiety.

The Pennsylvania State Weather Service was organized by the Institute in 1887. Its affairs were directed from here with a staff of voluntary observers throughout the state. The Service was in coöperation with the United States Signal Corps, and one of its members was stationed in Philadelphia for the purpose of directing the activities. The office was continued until 1891 when the state discontinued the small annual appropriation which paid for the necessary clerical work.

The smoke nuisance which is such an important problem, especially in large cities, was given consideration in 1887 and again in 1897. Every phase of the subject was considered: fuels, stoking, draft, smoke-consuming devices, mechanical stokers, etc. As a result of these discussions Philadelphia became a cleaner and healthier place in which to live, and continued so until our entry into the World War. Then came the "fuelless Mondays" and soon after industrial establishments and householders were permitted to use bituminous coal for fuel. The suspension of ordinances against smoke prevention nullified all the good that had been accomplished up to that time, and I think a reconsideration of the smoke nuisance would not be improper at this time.

The talking machine, the successor to the phonograph, was first described here in May 1888 by Mr. Emile Berliner of Washington, D. C., its inventor. The first impression of this piece of apparatus was not very favorable, but it became

more and more popular during the years following, and is still well known as the Victor Talking Machine.

In 1893, Mr. Reuben Haines, a chemist, specializing in water analysis, an active member of the Institute, made an examination of many of the springs and wells in East and West Fairmount Park and on the Wissahickon Drive. Twenty-eight samples of water were collected from as many springs and wells and it is interesting to note that at that time water of only one spring on the Wissahickon Drive could be considered pure and that the water of two of the wells was more pure than that of most of the springs. Two springs were contaminated by rinsings of ice cream cans from a nearby park restaurant. And yet we find people today who drive to Fairmount Park with containers which they fill with "pure" park water for drinking purposes.

In 1895 the management concluded that the Institute should have an appropriation from the state. Its services to state and nation had been frequent, and as can easily be ascertained, valuable. Accordingly, application was made to the legislature. An invitation was also extended to the members of that body to visit here and see how things were done, what we had accomplished and what we hoped to achieve in the future. A regular monthly meeting was selected for the purpose of showing ourselves off. The invitation was accepted and a joint committee from the House and Senate was appointed to pay us a visit.

In the meantime we had cleaned up a bit and had prepared a splendid program. The committee arrived in due time, composed of famous statesmen and numerous politicians of that day. They were escorted by one of our own members, who had much experience with groups of this kind. The meeting was gotten under way, the star attraction being a paper on acetylene, with a fine line of experiments. Everything was going well, we had an interested and impressive audience. The speaker gave an interesting account of the progress made in the utilization of acetylene. His experiments were under way. He had two dishes of calcium carbide on the table, uncovered both and added water. He ignited one and described his demonstration. Something went wrong—the unlighted dish was fuming and caught fire.

A cloud of smoke rose to the ceiling and began to descend in the form of large flakes, before the fire could be extinguished. One of the audience described it as a black snow. The visitors were soon covered with a greasy soot—collars, faces, clothing, hands, everything. Some immediately reached for their handkerchiefs and made matters still worse.

Nevertheless, the meeting was a success. Everyone was in a jolly mood; the visitors were given an opportunity to wash up and were then taken to a nearby restaurant for the customary treat. The appropriation was, however, never approved. This may be due to the fact that the characters of our visitors had been blackened during the visit.

In 1899 the Institute was invited to coöperate with the Commercial Museum in the management of the National Export Exposition. This exhibition was of a more recent World's Fair type and included the first Midway in a Philadelphia exhibition. This, as most of you know is a street of amusements and has little to do with the exhibition, but it is a great money maker. During the continuance of this exhibition the Institute commemorated its seventy-fifth anniversary in the Convention Hall of the exhibition. The celebration occupied one week, from October 2d to 7th, inclusive, and was a great success. Of the gentlemen who spoke on that occasion only two are living today.

We hear so much about voting machines these days. There still seems to be an impression among some voters that these new-fangled things are no good. However that may be, there was exhibited in this hall on January 16, 1901, thirty-two years ago, a voting machine which seemed to fill all requirements, and after the meeting it was installed in the reading-room where it remained for some weeks. The Committee on Science and the Arts examined this and another similar machine, and recommended the award of the John Scott Medal and Premium to the inventors of both.

The Mississippi River Floods, an ever present and serious problem, is sanely discussed in an article, "Controlling the Floods of the Mississippi River," by Prof. Lewis M. Haupt, in the JOURNAL OF THE FRANKLIN INSTITUTE for October 1903.

We likewise are all interested in the dial telephones, one of

the most recent inventions, praised by some and condemned by others. Some of you need only be reminded that on January 21, 1909, an automatic telephone system was installed and in operation in this hall. Telephones were located in various parts of the building and the mechanism which took the place of the human operator was on this floor in a glass case, where everyone could see what happened when a call was made. These few statements recall to my mind the closing quotation of a lecture given here many years ago by one of our mechanical engineers—"There is nothing new under the sun; what has been is to come, and what is to come has been."

The first flight of a Curtiss biplane from Jersey City to Philadelphia was made by Charles K. Hamilton on June 13, 1910. He started at the same time as a Pennsylvania Railroad train and made his landing two minutes ahead of the train.

The first public flight by a Farnum biplane in Philadelphia was made from Point Breeze Park, November 22, 1910, by Graham-White, a British pilot. On this occasion Prof. Samuel A. King, noted balloonist, then eighty-two years old, was a passenger. A photograph of this event was also made by Mr. Jennings on a specially designed 8 × 10 hand camera. Both these slides were shown here soon after the pictures were taken.

In 1916 the first public demonstration of transcontinental telephony was given in this hall, under the auspices of the American Telephone and Telegraph Company. Each chair was supplied with a telephone receiver and those present were able to listen to the chairman's conversation with members of the Institute and others in San Francisco.

In 1924, September 17th, 18th and 19th, the Institute observed the centennial of its founding. This celebration is so recent that it is only necessary to refresh the memory. There were nearly eight hundred delegates from all parts of the world and the gathering included a larger group of Nobel prize winners than had ever been together at any one time. Meetings were held in our own hall, the Walnut Street Theatre, the University of Pennsylvania and the Academy of Natural Sciences.

On the morning of the last day of the proceedings a tablet

was unveiled in the temporary buildings of the Bartol Research Foundation. This institution, founded by the late Henry Welchman Bartol, had only recently begun to function.

To relieve the monotony of the technical meetings, a garden party was held on one afternoon, and a banquet in the ball-room of the Bellevue-Stratford Hotel on Friday evening was the closing ceremony of the celebration. About six hundred members, friends and delegates attended this brilliant affair.

By the change of a single word, it would be proper to apply the frequently quoted lines from Tennyson's brook to one activity of the Institute: "Men may come and men may go, but *we* go on forever." The Committee on Science and the Arts, a unique organization, the only one on earth, has been active since the founding of the Institute, first as the Board of Examiners, later as the Committee on Inventions, and now under the title first given. Prior to 1887, any member of the Institute who signified his willingness to do so, could serve on the Committee. Fifty years ago it met in a room on the second floor, and I recall seeing that room entirely filled by those volunteers, with from three to six grouped around the doorway trying to follow the proceedings.

Did this Committee work? I can testify that it always has. The members have always felt that their services, while given freely, were of greatest importance to the progress of the Institute and the enhancement of its reputation. The volunteer committee continued until 1887, and the then Secretary in sending the notice of the last meeting to the faithful group headed the postal card—

MORS OMNIBUS COMMUNIS.

(Death is common to all)

In the following month, the newly elected committee convened and continued the work of its predecessors. The new committee consisted of forty-five members, fifteen being elected each year by the Board of Managers. In 1903 the number was increased to sixty, twenty being elected each year. In 1909 it was felt that new regulations were desirable,

and the committee spent the next several months in revising all of its by-laws. I can assure you that period was a busy one. Meetings were held frequently (seven in three months). My duties at that time were to record the proceedings of the meetings, and as I look back, I am surprised that I was able to get sufficient material from the discussions for permanent records. There were motions, amendments to motions, withdrawals of motions, points of order, etc. I was successful in straightening out my notes only with the help of the older and wiser heads. This Committee has examined and reported upon 2970 inventions during the past century.

One of the important activities of the Institute is its JOURNAL. The JOURNAL OF THE FRANKLIN INSTITUTE is the oldest technical publication in this country and has continued uninterruptedly since January 1826. In 1825 there was published in New York City the *American Mechanics Magazine*, by C. S. Williams, under the editorial direction of Dr. Thomas P. Jones. Those wise and far-seeing founders of the Institute purchased this publication lock, stock and barrel, including its editor Dr. Jones.

The title of the publication was changed to the *Franklin Journal*, which made its first appearance in January 1826. In January 1828 the title was changed to the JOURNAL OF THE FRANKLIN INSTITUTE. Dr. Jones continued as editor and also was appointed professor of mechanics, recording secretary and curator of the Institute. In 1828 he was made superintendent of the United States Patent Office, the second to hold this office, by Henry Clay, then Secretary of State, but continued his editorship until 1836.

In the early years I was a sort of refined printer's devil. I carried manuscripts and proofs to the various members of the Committee on Publication who in those days lived nearby, and copy and proof to our printers, who were then at 5th and Chestnut Streets. In recent years I have been a little more intimately connected with the JOURNAL. I have been permitted to insult the printers when the issues are not on time and I quarrel with the engravers when the illustrations are not satisfactory. Notwithstanding these handicaps the JOURNAL has progressed.

For many years each issue was confined to eighty pages,

but today it is more nearly one hundred and forty pages each month. Its character has changed somewhat with the changing years, but there has been no lowering of the standards set by its original founders. Volume 215 is now in the course of publication, and it is not likely that anyone shall ever be able to say in this case "Death is common to all."

While the circulation is not as great as that of the *Saturday Evening Post*, it can be found in every civilized country, including: Java, Formosa, India, Scandinavia, Denmark and South Africa. More copies go to Japan than to any other single country. This may be one reason why Japan is so successful in its brotherly argument with China.

I have said little as yet about the library. The collections have grown from 18,000 to 100,000 volumes, during the past fifty years. The pamphlet collection contains over 33,200 documents; about forty years ago it consisted of almost the same number, but there were then included pamphlets on subjects which had no bearing on the Institute's activities. These were finally eliminated by exchange, gift and otherwise, and we now have a pamphlet collection on technical subjects only.

The library occupied the greater part of the second floor up to 1897. By that time it was discovered that the alcove arrangement would have to be abandoned. It was therefore decided to fireproof the front portion of the second floor and erect in that space a modern two-story steel book stack. In the spring of 1898 we were able to place our entire collection of bound and unbound books (about 48,000) into the new stack with some space for growth. It was only a short time before it became necessary to find additional space, and today every available part of this building is being used for library purposes. The school-rooms on the third floor are devoted to the storage of books. Unbound magazine files are in the basement as are also several thousand books. The space under the seats in this hall is also being used for less frequently consulted works of reference.

The endowment funds, large and small, now number a dozen—in 1883 we had only one. The societies and publications with which we were in exchange relations in 1883 numbered 208, last year there were 545. The material which

is received in exchange for the Institute's Journal is most valuable to the library; it includes the best magazines on technical subjects and the transactions and proceedings of the learned societies of the world. In 1883 the total number of volumes bound was 244; in 1932, 1,919 volumes were bound. We have always prided ourselves on the completeness of our periodical sets. There are some 1,400 on our shelves and many of them are bound. During the past year we received 918 periodical publications; this included weeklies, monthlies, quarterlies, etc.

The World War interfered seriously with this class of publications. The mails of Germany were seized by the British and in some instances the mail-carrying steamers were sunk. After the entry of the United States into the war the mails were discontinued entirely and our sets of magazines were much impaired. It is only now that we are able to obtain missing numbers. We have recently completed our German patent reports by the purchase of seven years of back numbers, and four years of the publication of the Society of German Engineers are now on the high seas.

Since the war the increase in the costs of technical works has been out of reason. Volumes of such works as Watt's Dictionary of Chemistry, which originally cost about five dollars per volume, would sell today for about four times as much. The work by Mellor "A Comprehensive Treatise on Inorganic and Theoretical Chemistry," of which twelve volumes have appeared, sells at fifteen dollars per volume; Friend's "Text-book of Inorganic Chemistry," sixteen volumes already published, vary in price from three dollars and seventy-five cents to eighteen dollars per volume. Single volumes on technical subjects cost from ten to twelve dollars. Not so many years ago they could be bought for five dollars or less. From this it will be seen that it is necessary to have a larger endowment—the larger the better.

The most important special collection in the library is undoubtedly that of the late Lewis S. Ware, devoted to the subject of sugar. The nucleus for this collection was made in Paris by the donor. Mr. Ware lived abroad for about thirty years and books and other material which he had gathered together, did not come to us until after his death. This

collection will eventually contain all printed material which has any reference to the subject of sugar.

Another unique collection is that made by the late Frederick H. Shelton of this city. It is devoted to the subject of windmills and includes a great deal of material in several languages as well as prints and illustrations from many sources.

The departments of chemistry and electricity are very complete.

The Librarian occasionally meets people who belong to that group known as genius, but every one of this group requires special treatment whether he deserves it or not.

Some years ago a gentleman walked into the library one day and asked to see what we had on sanitary engineering. I saw here an opportunity to show off our collections. Not so many years ago it was possible, in most cases, to carry the best books on a subject in one armload. Today it is necessary to take a three-deck truck and make several trips. I made a selection of the latest and most used books on the subject and brought them to our visitor. He was still standing up when I appeared, and without giving me an opportunity to put the books before him said "What are you bringing me all that stuff for? I have seen all those. I am Mr. ———." He was credited with knowing more about the subject than was contained in all the books in our library. The scientists have not yet devised an enthusiasm scale, but I assure you my enthusiasm dropped from 70° to 28° F., C., K., or B.T.U. That gentleman was a great engineer, but a poor sport.

Then we meet the young college student—I hope freshmen only. Periodically these young men come to us for help and on several occasions we have been given slips on which were written what I suppose they imagined to be the titles of the magazines they needed:

IBID: 139, 672

We have always been able to help these young men without disclosing to them the fact that they needed further coaching in their Latin.

In my mind's eye I can see the hosts of technologists, experts in every branch of applied science, who have passed

through these halls in years gone by. Some came to visit, others to confer, some to lecture, many to receive honors and still others to commemorate with us some unusual event in science.

Many have passed on and some have been forgotten, a few are still with us. To name them all would be a task. The mention of a few may refresh your memory and bring back pleasant recollections:

Sir Charles A. Parsons, of steam turbine fame.
Dr. Pieter Zeeman of the University of Amsterdam.
Dr. Michael I. Pupin, physicist.
Dr. F. Haber, German chemist.
Sir William Bragg and his son, Prof. W. Lawrence Bragg, noted for their studies of crystals and crystalline structure.
Prof. C. V. Raman, physicist of Calcutta.
Dr. H. Carrington Bolton, a chemist and noted bibliographer.
George E. Waring, sanitary expert.
Dr. T. Sterry Hunt, of Canada.
Ira Remsen, noted chemist.
Edward Weston, electrical engineer.
Frank J. Sprague, father of electric railways.
George F. Kunz—expert in gems.
Nicola Tesla, electrical engineer.
E. L. Zalinski, U. S. Army, inventor of pneumatic dynamite gun.
J. B. Bernadou, U. S. Navy, of Spanish War fame.
Edward G. Acheson, the first to make artificial graphite.
Angelo Heilprin, a Philadelphian, who risked his life to look into the crater of Mt. Pelee at Martinique between eruptions.
Dr. Robert W. Wood, experimental physicist.
Harvey W. Wiley, the great food chemist.
Allen Hazen and W. P. Mason, sanitary engineers, especially noted as experts on water and water supplies.
Leo H. Baekeland, whose Bakelite will not soon be forgotten.
Richard Moldenke, expert iron founder.
Sir Joseph John Thomson, who came to us to deliver a series of lectures on "The Electron in Chemistry."

Dr. F. W. Aston, also a visitor from England who discussed "Atoms and Isotopes," on several afternoons.

Prof. Cleveland Abbe, father of the U. S. Weather Bureau. The Franklin Institute and the American Philosophical Society had their own weather service more than 100 years ago.

Sir Ernest Rutherford, noted for his investigations in radio-activity.

Albert A. Michelson, American physicist.

Ralph W. Pope, for many years closely identified with the American Institute of Electrical Engineers.

Capt. O. E. Michaelis, U. S. Army, who contributed papers to the Institute's JOURNAL and delivered a lecture on "The Army of Kukuanaland," and I imagine I hear again as I did in 1889 the question "Where is Kukuanaland?" It is the mythical country described by Allen Quatermain in Rider Haggard's "King Solomon's Mines." Rider Haggard is seldom read and his best seller is in the limbo of forgotten things.

Thomas A. Edison.

Lee De Forest, pioneer in the development of wireless telegraphy.

Alexander Graham Bell, father of the American telephone.

The corner stone for this building was laid with impressive ceremonies by the Grand Lodge of Masons of Pennsylvania on June 8th, 1825, and it was ready for occupancy early in the following year. Before ten years had passed the membership began to feel the need for a new building and in 1836 it was agreed to purchase the Masonic Temple on the north side of Chestnut above Seventh Street for $110,500. The financial crash of 1837 made it necessary to abandon the plans which for a time had looked so promising. Of the $40,000 which had already been paid, $30,000 were lost. After that the management became a little more cautious in its projects for new buildings, but there were many suggestions and in some instances very elaborate plans were prepared.

During the past fifty years there have been numerous efforts made to obtain a new building for the Institute. One thing, the most important one, was always lacking—the funds. It was not until 1930, one hundred years later, that the under-

taking became a reality under the leadership of Mr. Cyrus H. K. Curtis. Ground for the new building was broken on June 18th, Mr. Curtis' eightieth birthday. I, the greatest of all skeptics, am fully convinced that we shall now have a new building.

For the past hour I have given you an account of some of the unusual occurrences during fifty years and I hope you have received some inspiration. I have always had a warm spot in my heart for the old Institute. I am glad to have been connected with it in its less prosperous days and I hope I may be privileged to spend some time with it during its Renaissance. Better days are coming and I beg that you will bear with us for the next few months and continue your interest in the years to come. If you will permit me I shall repeat the final salute to the Institute made by the Hon. Frederick Fraley, the historian of the semi-centennial, fifty-nine years ago: "Esto Perpetua," or in good English "May it last forever."

Appreciation of Mr. Rigling's services by Professor Walter T. Taggart:

DR. TAGGART: We have heard a very interesting account of what may be called "The Second Half-Century" of the life of this venerable institution.

No one has been more closely associated with its activities and progress during this period than our librarian, Mr. Alfred Rigling.

His service has been one of devotion and self-sacrifice; his is known far and wide for his good deeds. His modesty is real; his friends are legion.

You have heard about the growth of the library—it will continue to increase in size and usefulness in its new home on the Parkway.

There are thousands of people who, like myself, have benefited by the information they have gathered here—not alone because a certain book or journal was on the shelves, but because Alfred Rigling was able to say that you will find what you are looking for in a certain place.

Mr. Rigling's information is encyclopædic—it is uncanny.

He has grown up with this library—he knows his books—

what they contain, and where to find them. The Franklin Institute library is what it is today largely on account of the service of Mr. Rigling.

What a service he has performed! The value of that service cannot be adequately estimated, but it will endure.

I join not only in extending my congratulations to Mr. Rigling on the completion of half a century of service and progress, but also in congratulating The Franklin Institute upon having had Mr. Rigling as Librarian. May his life of usefulness and happiness long be continued. Again I congratulate him.

Spirals in Nature.—(*Science*, **76**, 406; **77**, 50.) Off and on for the past two years various persons have recorded in *Science* their observations on the twisting of the grain in trees. Generally the author of the communication has concluded with a statement of opinion that the twisting of tree trunks and limbs is caused by the wind and supported the opinion with a very logical interpretation of the data observed.

At a more recent date E. H. HERRICK submits an account of his study of 1,527 trees, largely long leaf pine, located in Louisiana. Of this number 364 (32 per cent.) were straight-grained, 811 (53 per cent.) showed a right-hand twist and 352 (24 per cent.) showed left-hand twisting. In 215 cases observed the limbs showed the same direction of grain as the trunk, except in four cases in which the limbs showed twisting and the trunks were straight. It was interesting to find that in any single tree the degree of twisting at the surface may be considerably greater than in the regions nearer the surface. As a result of this study Herrick concludes that prevailing winds were not the cause of the twisting in these trees.

Now comes WILLIAM SEIFRIZ, who agrees with the negative conclusions of Herrick and proceeds to show through a series of analogies that such twisting is an inherent characteristic of the tree's protoplasmic matter. That it is not uncommon for Nature to develop a case of "spirals" through constitutional rather than external mechanical influences.

Examples are plentiful. In non-living matter both right-hand and left-hand crystals are to be found. The precipitation of salts in gels, known as the Liesegang phenomenon, is ordinarily rhythmic, resulting in the production of concentric rings, but occasionally a perfect spiral is produced, for which there is no adequate explanation. It has been reported that the Amœba, one of the lowest forms of animal organisms, travels in a spiral when moving along a thin glass rod or within a fine capillary tube. The shells of mollusks are striking examples of the spiral habit in organisms.

Schaeffer regards man as a spirally twisted right organism not only in respect to movements but in bodily structure as well. The gall-duct displays a marked right-spiral twist. As for movement, when man is blindfolded he walks in a right spiral and before dogs lie down for a nap they turn round and round.

Coming back to the plant kingdom, four distinct classes of spirals have been observed in cotton fibers. Reversal from right twist to left twist often occurs in the same fiber. The spiral habits of vines and tendrils are well known. Thus arises the conclusion that spiral development among organisms is the expression of a wide-spread tendency which is protoplasmic in origin. C.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

REVISION OF THE INTERNATIONAL ELECTRICAL UNITS.

E. C. Crittenden, chief of the bureau's electrical division, sailed on January 13 to attend the third biennial meeting of the advisory committee on electricity and photometry established by the International Committee on Weights and Measures. The meeting opened on January 31 at the International Bureau of Weights and Measures which is located at Sevres, near Paris.

The International Committee has undertaken to revise the present international electrical units. It proposes to base the units directly upon absolute measurements in the electromagnetic centimeter-gram-second system, instead of defining them by means of the mercury-ohm tube and the silver voltameter. Redeterminations of the ohm and ampere by absolute measurements are in progress in several national standardizing laboratories, including the Bureau of Standards; at the present meeting plans are being made for comparing the results found in different countries and for furnishing to all countries standards based upon the combined results.

The International Committee likewise hopes to establish uniform units and standards throughout the world for the measurement of light. In this attempt it is collaborating with the International Commission on Illumination. A special committee on units and standards appointed by the latter Commission, and consisting of representatives France, Germany, Great Britain, Japan, the Netherlands, and the United States, met in Paris on January 30 to prepare recommendations on photometry for the official advisory committee.

The bureau has proposed the establishment of a system of photometric units based primarily upon the intensity of the light given by a "black body" radiator at the freezing point of platinum (See Technical News Bulletin No. 151, November, 1929, and No. 170, June, 1931). The adoption of such a

* Communicated by the Director.

basic unit must be supplemented by agreement upon a method for measuring lights differing from that of the basic standard in color. The flicker photometer, with proper allowance for the characteristics of individual observers, affords one of the most simple and practical methods for making such measurements. Its use has, however, not been viewed with favor abroad. Consequently, a basis for international agreement is being sought in spectrophotometric measurements of colored filters, from which standard values for transmission of visible light can be calculated by means of "visibility factors" which have already been accepted by the International Commission on Illumination.

In both of these projects the National Physical Laboratory of Great Britain and the Bureau of Standards have been cooperating. Mr. Crittenden therefore visited London on his way to Paris in order to compare experimental results found at the bureau with those of the British laboratory. These two laboratories have joined in proposing that the new units in electricity and in light be put into general use on January 1, 1935. An alternative proposal is that their introduction be deferred until 1937. The most important duties of the 1933 meeting are to choose between these dates and to agree upon a definite schedule for carrying out the series of comparisons and interchange of standards which will be necessary.

RECOMPARISON OF PRIMARY STANDARDS OF RADIATION.

During the past month an examination has been made into the status of the bureau's primary standards of radiation, copies of which are issued to biologists, botanists, photochemists, physicists, physiologists, etc., who desire to equate their radiation stimuli in absolute value.

These standards of radiation consist of 50-watt, 115-volt, anchored carbon-filament incandescent lamps which have been seasoned, and calibrated for voltage and current in accordance with the accepted procedure in preparing similar standards of luminous intensity.

The first standards of radiation were obtained in 1913 by direct comparison of a group of lamps against a black body, and subsequent standards were obtained by comparison with this first group of lamps.

The present inquiry was prompted by a published report that copies of these standards deteriorate in radiant flux at the rate of 0.5 per cent. per hour, which is contrary to all previous experience in the use of such lamps as standards of luminous intensity and as standards of radiation.

In 1918 an intercomparison of 6 of these radiation standards showed a deviation of 0 to 3 parts in 1,000 from the values of the radiant flux assigned to each lamp in 1913, which deviation is entirely within experimental errors.

In 1930 an intercomparison of 9 primary standards of radiation, including three of the originals (of 1913) which had not been used for 12 years, showed a maximum deviation of 3 parts in 1,000; again entirely within experimental errors, and none differing systematically from the intercomparison of 1918.

On recalling the three lamps that were reported to be deteriorating in radiant flux, one was reported destroyed by arcing in the socket.

The second lamp, which was reported to have deteriorated in radiant flux to the extent of 3.1 per cent. in 9 hours, was found unchanged to less than 3 parts in 1,000. Similarly, tests with a potentiometer showed no changes in the volt-ampere calibration.

The third lamp of this group was found to have increased (instead of decreased) in radiant flux by almost 1 per cent. caused apparently by a hot spot in the filament, which appeared much brighter (hotter) than the rest of the filament, on continuous operation. On closing the circuit momentarily this spot became red hot before the rest of the filament began to glow. Whether this injury in the filament occurred in shipment is unknown.

The conclusion of this inquiry is that there is no appreciable deterioration in the standards of radiation issued by the bureau, though unavoidably some may become defective. In a life test now in progress, on a standard of radiation, after operating it 176 hours the radiant flux has decreased by less than 3 parts in 1,000 from the value observed at the beginning.

SATURATION SCALE FOR YELLOW COLORS.

The relationship between colorimetric purity of the stimulus and saturation of the color evoked under specified observing conditions has been determined at the bureau for yellow colors by using the yellow series of Lovibond glasses. Two observers have selected glasses from this series requisite to produce a scale progressing by equal steps from white to yellow. These results have been compared with previous experimental results, and with two empirical relations. Glasses representing the four scales compared have been grouped together and judgments obtained from eight observers as to which group formed the most satisfactory scale with the result that the new experimental scale has been corroborated. This information is useful in developing a method of writing uniform color tolerances.

SOME IMPROVEMENTS IN PSYCHROMETRY.

Air humidity is generally measured by noting the reading of a thermometer having a bulb encased in wetted cloth, and simultaneously measuring the temperature of the air with an ordinary thermometer. From the two readings so obtained, the air humidity can be found by means of a table or chart. This combination of a wet-bulb and a dry-bulb thermometer is called a psychrometer.

With proper care in its use, the psychrometer will give rather accurate values of humidity under normal weather conditions. However, when it is either very hot or cold, or very dry or wet, rather large errors occur despite the best of care. The instrument simply does not function correctly under such conditions.

By slightly modifying the conventional ventilated psychrometer, the Bureau of Standards has found it possible to correct these errors; the resulting instrument is quite accurate at all humidities up to 90 per cent. and up to at least 150° F. air temperature. In studying the instrument, it was also tested and found accurate under reduced air pressures equivalent to altitudes up to 32,500 feet.

A new chart for obtaining either relative or absolute humidity from the psychrometer readings has been developed.

This chart is both simpler to use and more accurate than those previously available.

VAPOR LOCK.

The computations of vapor handling capacities of the fuel systems in fifty automobiles on which vapor lock data were obtained by the bureau, have been completed. Using these values as a basis it has been possible to evaluate, with considerable accuracy, the permissible vapor pressures for freedom from vapor lock in these cars when operated under a variety of conditions on diverse types of fuels. This analysis of the vapor lock results indicates that changes in design of fuel feed systems so as to increase the vapor handling capacity may be very effective in increasing the freedom from vapor lock troubles. This procedure has, however, the disadvantage that fuel economy is decreased at the same time so that it is preferable to confine most of the efforts in redesign towards lowering of the fuel line temperatures. It is believed that a Reid vapor pressure limit of 8 pounds is satisfactory up to atmospheric temperatures of 37.7° C. (100° F.) and that a 12 pound gasoline may be used satisfactorily up to atmospheric temperatures as high as 23.8° C. (75° F.). Further work is being undertaken to verify these limits for different types of gasoline.

The conclusions drawn from this analysis of the test data obtained in the vapor lock road tests were incorporated in a paper entitled "The Vapor Handling Capacity of Automobile Fuel Systems" which was presented at the annual meeting of the Society of Automotive Engineers last month.

STABILITY OF GREASES.

The Bureau is conducting an investigation of the effect of temperature on the bleeding of greases. It has been found that the change in the amount of bleeding, with increase in temperature, varies markedly for different types of greases. Thus, in some cases the amount of bleeding will increase as the temperatures increase, while in other cases the reverse is true. Believing that hardening of the grease due to loss of

moisture on heating might account for the decrease in the extent of bleeding with increased temperature, some special experiments were undertaken to determine whether this was actually the case. In these special experiments the greases were heated to the temperature of test and allowed to remain at that temperature for a given period of time after which they were cooled. By comparison of the amount of bleeding before and after this heating process, it was concluded that loss of moisture may have some effect, but that more probably the grease sets with a different gel structure after heating, with resultant increase in hardness. Further work on this phenomena is under way.

EXTREME PRESSURE LUBRICANTS.

Data on load-carrying capacity of lubricants have been obtained with the Timken machine at speeds from 150 to 950 r. p. m. and at temperatures from 25 to 125° C. using four extreme pressure lubricants. Similar information has been obtained on the modified Floyd machine at speeds from 100 to 1,300 r. p. m. and at temperatures from 25 to 125° C. using eight oils. From these data the following conclusions are indicated:

(1) The load-carrying capacity of an extreme pressure lubricant tends to decrease as the rubbing speed increases.

(2) The load-carrying capacity of an extreme pressure lubricant tends to decrease as the temperature increases.

(3) The effects of speed and temperature differ with the particular lubricant and machine involved to such an extent that even the order of reading may be changed.

(4) No set of operating conditions was found with the machines which would even rate the lubricants in the same order.

The information which has been obtained in the investigation of extreme pressure lubricants up to date was assembled in a paper entitled "The Load-Carrying Capacity of Extreme Pressure Lubricants" which was presented to the Society of Automotive Engineers at their annual meeting in January.

FIRE TESTS OF GYPSUM LATH PARTITIONS.

Several fire tests of partitions covered with plaster on gypsum lath have been conducted recently as a part of the general series of fire tests of framed partitions. The lath, ⅜-inch thick and consisting of a core of gypsum with outside paper facings, was applied in the form of 16 by 48 inch boards to both sides of 2 by 4 inch pine studs spaced 16 inches on centers. For two partitions the lath was perforated with ¾-inch round holes spaced 4 inches on centers each way, as aid in obtaining a good key for the plaster.

The gypsum plaster was either neat fibered or sanded in the proportion one part plaster to two parts sand by weight, the thickness over the lath inclusive of a white coat finish being one-half inch. The partitions were 16 feet long and 10½ or 11 feet high and were tested in the large wall and partition furnace. The fire exposure was controlled according to established procedure so that furnace temperatures near 1,550° F. were indicated one-half hour after the start of the test, 1,700° F. at one hour, and 1,792° F. at 1½ hours. Failure in wall and partition tests is determined by occurrence of an average temperature rise under asbestos pads on the unexposed side in excess of 250° F. above the initial or of 325° F. at any point, transmission of flame, or failure to support load. In the present tests a load of 30,550 pounds (358 lbs./in.² of wood stud) was applied to four of the partitions subjected to the fire endurance tests. The other two were tested restrained within the frames in which they were built, one being subjected to a fire endurance test and the other to a fire and hose stream test. In the latter test the partition was subjected to the fire test for one-half hour after which a hose stream from a 1⅛-inch nozzle under a pressure of 30 lbs./in.² was applied for 2⅔ minutes to the side exposed to fire. The hose stream washed off the plaster on the exposed side that had not fallen during the fire exposure, as also the lath, but did not penetrate the facing on the unexposed side of the partition.

The results of the fire endurance tests are given below:

Lath.	Plaster.	Time to Failure. Hr. : min.
Plain	Neat fibered	0 : 58
Plain	Sanded 1 : 2	0 : 55
Perforated	Sanded 1 : 2	1 : 28

Failure was due either to inability to sustain load or to temperature transmission, the one occurrence following the other so closely in some tests as to make it difficult to determine which was the primary cause.

The 50 per cent increase in fire resistance with the perforated plasterboard over those with the plain board can be ascribed to the better key for the plaster given by the perforations. Although perforated plasterboard had been used experimentally as early as 1915 (Bureau of Standards Technologic Paper No. 70), it had not become commercially available until within the past year. The performance enables the partition construction employing this lath to qualify with a considerable margin on fire endurance for the one-hour rating required for corridor and subdividing partitions according to some building codes. With the wood stud supports, its use would be restricted to locations in buildings where combustible constructions are permitted. Partition constructions have been developed employing plaster board applied to metal supports but no fire tests with perforated plasterboard or lath so applied have been made.

STORAGE OF GOVERNMENT RECORDS.

In planning the National Archives Building, now under construction in Washington, every reasonable precaution is being included for the preservation of valuable Government records. At present there is no general depository for the records and they are scattered through many buildings, exposed variously to danger of loss by fire, theft, and deteriorative influences.

In addition to the usual protective measures against loss through fire, and other visible and well-recognized enemies, unusual precautions have been taken to guard against insidious enemies of paper and bindings, such as light, and air not properly tempered and purified. In planning the defense against such deteriorants of records, the recommendations of the bureau were followed. These are based upon an extensive study of the preservation of records in libraries conducted by the bureau with the assistance of funds granted by the Carnegie Foundation to the National Research Council.

While it has been generally known that light is not favorable to the preservation of paper, the bureau has shown that its destructive effect is more rapid and intense than commonly appreciated. In the Archives Building, daylight will be entirely excluded from the storage spaces; small incandescent bulbs turned on only as needed will supply the necessary illumination.

A large air-treating system capable of handling 330,000 cubic feet of air per minute will insure the purity and proper tempering of the atmosphere throughout the building. A new feature will be the washing of the air with an alkaline solution to remove positively any acidic contamination which might otherwise find its way into the storage space. The bureau's work has shown conclusively that acid gases, especially sulphur dioxide, widely produced by the combustion of fuels, accelerate the deterioration of all kinds of papers. The temperature and moisture content of the air will be carefully controlled, for high temperature and extreme dryness promote embrittling of paper, while too much moisture may cause molding. It is planned to maintain a relative humidity of 55 per cent in the storage spaces, and of 45 per cent in the work rooms. The latter condition is better adapted to human beings. The temperature throughout will be kept at 70° F. during the winter and 80° F. during the summer. The higher temperature during hot weather is more economical, and is more healthful for the personnel as it avoids sudden exposure to too great a change in temperature in entering or leaving the building. Continuous maintenance of the humidity within 2.5 per cent. and of the temperature within 1° above or below the chosen conditions, is believed feasible.

Another interesting precaution is the use of glazed tile and the incasing of concrete columns in non-ferrous metal to minimize abrasive dust. Coated or non-ferrous metals will be used where metal is required in the storage spaces to eliminate the necessity of repainting which would be hazardous to the stored records.

This archives building can well serve as a model for the housing of valuable records of all kinds, since in planning it every advantage has been taken of the most advanced architectural, engineering, and scientific knowledge.

Early Lectures on Science in Philadelphia.—The School of Medicine of the University of Pennsylvania is the oldest medical college in English North America. During the first century of its existence, each professor issued tickets to his lectures to the students. The present Dean of this School, WILLIAM PEPPER, has published (*General Magazine and Historical Chronicle*, 1933, xxxv, 158–163) pictures and a description of the tickets issued to James Armstrong, who was among the matriculates on the founding of the School in 1765, and graduated with its degree of Bachelor of Medicine in 1769. Among the subjects and the professors issuing the tickets are Natural and Experimental Philosophy by John Ewing and Hugh Williamson, Chemistry by Benjamin Rush, Botany by Adam Kuhn, and Anatomy by William Shippen, Jr.

J. S. H.

Test for Nitrites.—IRWIN STONE (*Chemist Analyst*, 1933, xxii No. 1, p. 10) applies the diazo reaction for the detection of nitrites. The reagent contains: Aniline 1 cc., phenol 1 gram, concentrated hydrochloric acid 15 cc., distilled water sufficient to make 150 cc. The solution to be tested is neutralized if necessary, treated with 0.5 cc. of the reagent, let stand for 30 seconds, then made alkaline with sodium hydroxide. If nitrites be present, a yellow color develops, which may be extracted with amyl alcohol. This test will reveal the presence of 0.01 milligram of nitrite ion in 1 cc. of unknown. J. S. H.

Vitamin C Content of Frozen Juice of Citrus Fruits.—The effect of prolonged storage in the frozen condition upon the antiscorbutic vitamin, water-soluble C, in the expressed juice of citrus fruits has been studied by two groups of investigators.

E. M. NELSON AND H. H. MOTTERN (*Ind. Eng. Chem.*, Industrial Edition, 1933, xxv, 216–218) report that orange juice, which has been frozen quickly and stored in hermetically sealed containers at a temperature of 0° F. for a period of 10 months, then permitted to melt at room temperature, has experienced no appreciable loss in this vitamin, which protects from the disease scurvy. Similar results are obtained when the air in the container is replaced by either oxygen or nitrogen.

LILLIAN W. CONN AND ARNOLD H. JOHNSON (*Ind. Eng. Chem.*, Industrial Edition, 1933, xxv, 218–221) find that storage of orange juice in the frozen condition for a period of 5 months does not appreciably reduce its vitamin C potency. Commercially prepared orange and grapefruit juices had a vitamin C content equal to that of the fresh juices. J. S. H.

THE FRANKLIN INSTITUTE

STATED MONTHLY MEETING, FEBRUARY 15, 1933.

The regular monthly meeting of The Franklin Institute was called to order at eight-fifteen P.M. by the President, Mr. Nathan Hayward.

The President immediately called upon the Secretary to read the Committee appointments which had been made either by the Board of Managers or the President. The appointments follow:

Comittee on Library: Mr. C. W. Bates, Dr. H. J. Creighton, Mr. W. G. Ellis, Mr. F. Lynwood Garrison, Mr. C. A. Hall, Dr. J. S. Hepburn, Dr. G. A. Hoadley, Mr. L. F. Levy, Mr. T. S. Rowland, Dr. W. T. Taggart.

Committee on Meetings: Dr. James Barnes, Dr. George S. Crampton, Dr. T. G. Delbridge, Mr. W. H. Fulweiler, Dr. A. W. Goodspeed, Dr. H. McClenahan, Mr. Charles Penrose, Dr. G. D. Rosengarten, Mr. James G. Vail, Mr. W. C. Wagner.

Committee on Science and Arts: Following members elected at this time, to serve three years: Dr. C. B. Bazzoni, Mr. F. P. Brown, Dr. G. S. Crampton, Mr. G. S. Cullen, Mr. O. B. Evans, Mr. J. L. Fitts, Mr. F. V. Hetzel, Dr. G. A. Hoadley, Mr. J. D. Lee, Jr., Mr. K. G. Mackenzie, Mr. F. H. Rogers, Mr. J. M. Rusby, Mr. W. L. Saunders, Prof. W. O. Sawtelle, Mr. E. W. Smith, Mr. J. C. Trautwine, 3d, Mr. J. A. Vogleson, Mr. W. C. Wagner, Mr. J. M. Weiss, Mr. H. W. Welles.

The Secretary also announced that Mr. Theobald F. Clark had been elected Chairman of the Committee on Science and the Arts for the present year.

The Secretary then moved that all further routine business be postponed until the next meeting in order that the evening might be devoted to the exercise which was held in honor of the librarian and assistant secretary, Mr. Alfred Rigling who, on February 13, 1933, completed fifty years of his services to The Franklin Institute. This motion was unanimously adopted.

The President delivered a short sketch of the development of the library and Mr. Rigling's influence, and then called upon the Secretary.

The latter presented the citation of Mr. Rigling and moved that he be elected to Honorary Membership in The Franklin Institute. This motion was adopted unanimously by a rising vote.

The President announced that Mr. Rigling was unfortunately absent because of illness but that his paper would be read by the Secretary of the Institute.

The Secretary then read the paper prepared by Mr. Rigling entitled, "Reminiscences of Fifty Years." The paper was heard with the greatest interest and was received with much applause.

The President called upon Professor Walter T. Taggart who read an appreciation of Mr. Rigling's services to the Institute. He then requested Mrs. Rigling to convey to her husband the expression of our profound regret at his illness and enforced absence, and of our genuine personal affection for him.

There being no further business the meeting was declared adjourned.

A public reception in honor of Mr. Rigling which was to be held in the Library of the Institute was cancelled because of the absence of the guest of honor.

Full transcript of the proceedings of this meeting appears in this number of the JOURNAL.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, February 8, 1933.)

HALL OF THE COMMITTEE,
PHILADELPHIA, FEBRUARY 8, 1933.

MR. EDWARD L. CLARK *in the Chair.*

The following reports were presented for final action:

No. 2937: Locomotive Booster.

This report recommended the award of the Edward Longstreth Medal to Mr. Howard L. Ingersoll, of New York City, "In consideration of his development of the locomotive booster to a state in which it gives valuable aid to locomotive performance and railroad service."

No. 2942: Multi-Motored Flying Machine.

This report recommended the award of the Howard N. Potts Medal to Mr. Igor I. Sikorsky, of Bridgeport, Connecticut, "In consideration of his pioneer work and inventions in the development of multi-motored airplanes of various types, for different uses, including amphibians and the largest combined planes for land and water service, and of his method of direction control of multi-motored machines by the use of an automatic stabilizer."

No. 2945: Autogiro.

This report recommended the award of the Elliott Cresson Medal to Senor Juan de la Cierva, of London, England, "In consideration of the original conceptions and inventive ability which have resulted in the creation and development of the autogiro."

The following report was presented for first reading:

No. 2967: Literature.

GEO. A. HOADLEY,
Secretary to Committee.

MEMBERSHIP NOTES.

ELECTION TO MEMBERSHIP.

(Stated Meeting, Board of Managers, February 15, 1933.)

RESIDENT.

MR. CHARLES EDGAR ZORTMAN, Civil Engineer, 39 North Seventh Street, Philadelphia, Pa. For mailing: 88 West Godfrey Avenue, Philadelphia, Pa.

NON-RESIDENT.

MR. EDWARD RICHARD HUGHES, Consulting Engineer, 80 John Street, New York City. For mailing: Mt. Kemble Avenue, Morristown, New Jersey.
MR. JOSEPH S. LAY, Salesman, Drugs and Chemicals, Palmyra, Pa.
MR. DOUGLAS SHEA, Atlantic City, New Jersey. For Mailing: Mays Landing, New Jersey.
DR. HUGH STOTT TAYLOR, Professor of Chemistry, Frick Chemical Laboratory, Princeton, New Jersey.

CHANGES OF ADDRESS.

PROFESSOR F. O. DUFOUR, 452 Sabine Road, Wynnewood, Pa.
DR. L. ASHLEY FAUGHT, 1414 Spruce Street, Philadelphia, Pa.
MR. PATRICK F. FOLEY, 7411 Fourth Avenue, Brooklyn, New York.
MR. JOHN J. GIBSON, 51 Allen's Lane, Mt. Airy, Philadelphia, Pa.
MR. H. ENNIS JONES, Benjamin Franklin Memorial, 2024 Fidelity-Philadelphia Trust Building, Philadelphia, Pa.
MR. W. LAURENCE LEPAGE, Land Title Building, Philadelphia, Pa.
MR. EDWIN M. WOODS, 225 South Forty-first Street, Philadelphia, Pa.

NECROLOGY.

Mr. John F. Lewis, Philadelphia, Pa.
Mr. E. M. Herr, New York City.

LIBRARY NOTES.

RECENT ADDITIONS.

ALLEN, RICHARD HINCKLEY. Star-Names and their Meanings. 1899.
American Society for Testing Materials. Index to Proceedings, Volumes 21–30 (1921–1930). Two volumes. 1927–1932.
Bulletin Almanac and Year Book. 1933.
CHAMBERLAIN, JOHN. Manufacture of Knitted Footwear. Prepared for the Textile Trades Advisory Committee of the City of Leicester Colleges of Art and Technology. 1930.
CHAMBERLAIN, JOHN. Hosiery Yarns and Fabrics. Prepared for the Textile Trades Advisory Committee of the City of Leicester Colleges of Technology and Art. 1926.
GROSS, HARDY, AND NEWLIN DOLBEY MORGAN. Continuous Frames of Reinforced Concrete. 1932.
Deutsche Lichtbild. Jahreschau 1933.
DORSCH, KARL E. Chemie der Zemente. (Chemie der hydraulischen Bindemittel.) 1932.
DUBRAU, MAX. Textilrohstoffe. Vorkommen, Gewinnung, Eigenschaften, Handel und Verspinnung. 1932.
EMMONS, WILLIAM H., GEORGE A. THIEL, CLINTON R. STAUFFER AND IRA S. ALLISON. Geology. First edition. 1932.

FRENKEL, J. Wave Mechanics. 1932.

GAUTTERMANN, L. Laboratory Methods of Organic Chemistry. Completely revised by Heinrich Wieland. Translated from the twenty-second German edition by W. McCartney. 1932.

GEIGER, H., AND KARL SCHEEL. Handbuch der physik. Zweite Auflage. Band 22, erster Teil; Band 22, zweiter Teil; Band 23, erster Teil. 1933.

GLASSER, OTTO. Wilhelm Conrad Röntgen und die Geschichte der Röntgenstrahlen. Mit einem Beitrag "Persönliches über W. C. Röntgen" von Margaret Boveri. 1931.

Göttingen, Aerodynamische Versuchsanstalt. Ergebnisse. Lieferung 1–4. Four volumes. 1923–1925.

GREGG, J. L. The Alloys of Iron and Molybdenum. First edition. 1932.

GRIMSEHL, E. A Textbook of Physics. Edited by R. Tomaschek. Authorized translation from the seventh German edition by L. A. Woodward. Volume I—Mechanics. 1932.

HALAMA, M. Transparentfolien. (Cellophan, Transparit, Heliozell, Ultraphan, usw.). 1932.

HEDGES, ERNEST S. Chapters in Modern Inorganic and Theoretical Chemistry. No date.

HEDGES, ERNEST S. Liesegang Rings and Other Periodic Structures. 1932.

HENNEY, KEITH, Editor-in-Chief. The Radio Engineering Handbook. Prepared by a staff of twenty-two specialists. First edition. 1933.

Institut International de Physique Solvay. Le Magnétisme. Rapports et Discussions du Sixième Conseil de Physique Tenu à Bruxelles du 20 au 25 Octobre 1930. 1932.

JAMIESON, GEORGE S. Vegetable Fats and Oils. The Chemistry, Production and Utilization of Vegetable Fats and Oils for Edible, Medicinal and Technical Purposes. 1932.

JUNK, VICTOR. Die Nobelpreisträger. Dreissig Jahre Nobelstiftung. 1930.

KETCHUM, MILO S. The Design of Steel Mill Buildings and the Calculation of Stresses in Framed Structures. Fifth edition. 1932.

KIESLINGER, ALOIS. Zerstörungen an Steinbauten: ihre Ursachen und ihre Abwehr. 1932.

Klimschs Jahrbuch. Technische Abhandlungen und Berichte. Die Neuerungen auf dem Gesamtgebiet der graphischen Künste. Band 26. 1933.

KYSER, HERBERT. Die elektrische Kraftübertragung. Zweiter Band: die Niederspannungs—und Hochspannungs—Leitungsanlagen: Entwurf, Berechnung, elektrische und mechanische Ausführung. Dritte vollständig umgearbeitete und erweiterte Auflage. 1932.

LADNER, A. W., AND C. R. STONER. Short Wave Wireless Communication. 1932.

LECAT, MAURICE. L'Azéotropisme: la Tension de Vapeur des Mélange de Liquides. Bibliographie. 1932.

LOWRY, STEWART M., HAROLD B. MAYNARD, AND G. J. STEGEMERTEN. Time and Motion Study, and Formulas for Wage Incentives. Second edition. 1932.

LÜBKE, ANTON. Der Himmel der Chinesen. 1931.

LYNCH, ARTHUR. The Case Against Einstein. No date.

McADAMS, WILLIAM H. Heat Transmission. First edition. 1933.

MARIGNAC, J.-C. GALISSARD DE. Oeuvres Complètes. Tomes 1–2. No date.

MELLER, KARL. Elektrische Lichtbogenschweissung. Handbuch für die Anwendung der Lichtbogenschweissung in der gesamte Industrie. Zweite wesentlich erweiterte Auflage. 1932.

MESSKIN, W. S. Die ferromagnetischen Legierungen und ihre gewerbliche Verwendungen. Umgearbeitet und erweitert von A. Kaussmann. 1932.

MILLER, CARL W. An Introduction to Physical Science. 1932.

MILLIKAN, ROBERT ANDREWS. Time, Matter, and Values. 1932.

MITTASCH, A., UND E. THEIS. Von Davy und Döbereiner bis Deacon: ein halbes Jahrhundert Grenzflächenkatalyse. 1932.

MÖHRINGER, KARL. The Bridges of the Rhine, Roman, Medieval, and Modern: an Account of Notable Bridges over the River Rhine and its Tributaries, with a Description of Those Recently Built. 1931.

MOULLIN, E. B. The Principles of Electromagnetism. 1932.

National Committee on Wood Utilization. Chemical Utilization of Wood by Henry K. Benson. 1932.

NEWENS, FRANK R. The Technique of Colour Photography. 1931.

PASCHKIS, VICTOR. Elektrische Industrieöfen für Weiterarbeitung. 1932.

PFLEIDERER, C. Die Kreiselpumpen. Zweite, verbesserte Auflage. 1932.

Photograms of the Year 1932. The Annual Review for 1933 of the World's Pictorial Photographic Work.

PIATTI, L. Die Wiedergewinnung flüchtiger Lösungsmittel. Die Lösungsmittel im Fabrikbetrieb, ihre Eigenschaften, Anwendung und Behandlung. 1932.

PLANCK, MAX. Theory of Electricity and Magnetism. Being Volume 3 of "Introduction to Theoretical Physics" translated by Henry L. Brose. 1932.

PLANCK, MAX. Theory of Heat. Being Volume 5 of "Introduction to Theoretical Physics" translated by Henry L. Brose. 1932.

PLANCK, MAX. Theory of Light. Being Volume 4 of "Introduction to Theoretical Physics" translated by Henry L. Brose. 1932.

REG, O. Byepaths of Colour Photography. Edited and with an Introduction by William Gamble. No date.

REISER, F. Das Härten des Stahles. Achte, gänzlich umgearbeitete Auflage, herausgegeben von Dr.-Ing. F. Rapatz. 1932.

SABINE, PAUL E. Acoustics and Architecture. First edition. 1932.

SCHÖNFELD, H. Die Hydrierung der Fette. Eine chemisch-technologische Studie. 1932.

Society of Public Analysts and Other Analytical Chemists. Some Reminiscences of its First Fifty Years by Bernard Dyer; a Review of its Activities by C. Ainsworth Mitchell. 1932.

TAMMANN, GUSTAV. Lehrbuch der Metallkunde. Chemie und Physik der Metalle und ihre Legierungen. Vierte erweiterte Auflage. 1932.

TAPSELL, H. J. Creep of Metals. 1931.

VALASEK, JOSEPH. Elements of Optics. Second edition. 1932.

WALL, E. J. Practical Color Photography. Second edition. 1928.

WHEELER, OWEN. Colour Photography. 1929.

WILLIAMS, J. GUILFOYLE. Textiles on Test. A Study for the Distributor and

Consumer of the Wearing and Washing Properties of Fabrics and Garments. 1931.

World Almanac and Book of Facts for 1933.

WOYTACEK, CARL. Lehrbuch der Glasbläserei. Zweite, neubearbeitete und erweiterte Auflage. 1932.

YOUNG, GEORGE J. Elements of Mining. Third edition. 1932.

BOOK REVIEWS.

LA THEORIE ATOMIQUE ET LA DESCRIPTIONS DES PHENOMENES, Quatre articles precedes d'une introduction. Par Niels Bohr. Traduction francaise de Andree Legros et Leon Rosenfeld. v-113 pages, 15 × 23 cms., paper. Paris, Gauthier-Villars et Cie., 1932. Price 20 francs.

Among the famous investigators who gradually have been bringing modern atomic theory into an orderly and connected form, Prof. Bohr has made contributions which are indicative of the stroke of genius which will finally achieve that end. Numerous authoritative accounts of the progress of these advances are extant, but a general survey by the author of these dominant contributions must arouse widespread interest.

The subject-matter is a chronological arrangement, duly revised, of four papers on the fundamental components of atomic theory. These are presented under (1) Atomic theory and mechanics (1925) (2) The quantic postulate and the latest development of atomic theory (1927), (3) The quantum of action and the description of its phenomena (1929), (4) Atomic theory and the fundamental principles of the description of its phenomena (1929). An introductory chapter (1929) with an addendum (1931) is included.

L. E. P.

ACOUSTICS AND ARCHITECTURE, by Paul E. Sabine, Ph.D. Riverbank Laboratories. 327 pages, illustrations, tables, 15.3 × 23.4 cms. New York, McGraw-Hill Book Company, 1932. Price $3.50.

A very great deal of thought has been given to acoustics by architects and engineers, as the author points out in the preface. This subject is bound to demand much more study as buildings of new type rise to replace old structures. The properties of sound, reverberation, absorption, control, measurement and transmission all have treatment in as many chapters.

The book is well prepared and freely illustrated. It will be useful to the student, engineer and designer of rooms and particularly halls where success or failure hangs upon the behavior of sound.

H. W. ELKINTON.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS:

Report No. 447, Static Thrust of Airplane Propellers, by Walter S. Diehl, 8 pages, diagrams, 23 × 29 cms. Washington, Superintendent of Documents, 1932. Price five cents.

Static thrust data from more than 100 airplane propeller tests are collected

from various sources and combined in working charts, from which the static thrust coefficient K_{T_0} in the equation

$$T_0 = \frac{K_{T0} \times b \cdot hp}{\text{r.p.m.} \times \text{diam.}}$$

may be readily determined. The available data cover practically all types of propellers and are in good agreement. For extreme pitch ratios, or for very low and for very high blade settings, the values of K_{T_0} are shown to deviate considerably from the generally used linear relations based on data at moderate pitch ratios.

Report No. 451, The Drag of Two Streamline Bodies as Affected by Protuberances and Appendages, by Ira H. Abbott, 8 pages, illustrations, 23 × 29 cms. Washington, Superintendent of Documents, 1932. Price five cents.

Two airship models were tested in the N.A.C.A. variable-density wind tunnel to determine the drag coefficients at zero pitch, and the effect of fins and cars and of flat and streamline protuberances located at various positions along the hull. During the investigation the stern of one model was rounded off to produce a blunter shape. The extreme range of the Reynolds Number based on the overall length of the models was from 1,300,000 to 33,000,000.

At large values of the Reynolds Number the streamline protuberance affected the drag very little, and the additional drag caused by the flat protuberance was less than the calculated drag of the protuberance alone. The fins and cars together increased the bare-hull drag about 20 per cent.

Report No. 453, The Estimation of Maximum Load Capacity of Seaplanes and Flying Boats, by Walter S. Diehl, 5 pages, diagrams, 23 × 29 cms. Washington, Superintendent of Documents, 1932. Price five cents.

It is shown that the relation between the gross load W and the time for take-off t of seaplanes and flying boats is of the form

$$W_m = W + K\frac{b \cdot hp}{t}$$

Where W_m is the maximum possible load corresponding to infinite value of t, $b \cdot hp$ is the total brake horsepower and K is a constant. Data from four tests give $K = 140$.

This equation supplies a method of calculating time for take-off with any load, or vice versa, when the time or one load is known.

PUBLICATIONS RECEIVED.

Mirrors, Prisms and Lenses, A Textbook of Geometrical Optics, by James P. C. Southall. 806 pages, ill., 13.5 × 21 cms. New York, Macmillan Company, 1933. Price $4.50.

Microenergetique, par Pierre Bricont, preface de M. Ch. Fabry, Tome I. 303 pages, 16.5 × 25 cms. Paris, Gauthier-Villars et Cie, 1933. Price 100 frs.

Atmospheric Electricity, by B. F. J. Schonland, preface by O. W. Richardson, 100 pages, diagrams, 11 × 17 cms. New York, E. P. Dutton & Co., Inc. Price $1.10.

An Outline of Atomic Physics, by the members of the physics staff of the University of Pittsburgh, 348 pages, illustrations, tables, 15 × 23.5 cms. New York, John Wiley & Sons, Inc., 1933. Price $3.50.

Le Mystere et le Paradoxe du vol Animal, par le Docteur Emile Batault, 236 pages, 16.5 × 25 cms. Paris, Gauthier-Villars et Cie, 1933. Price 50 francs.

Movimiento Central de Los Astros, por Carlos West, 150 pages, diagrams, tables, 14 × 19 cms. Buenos Aires, Ricardo Gutierrez, 1932.

Ontario Department of Mines, Forty-first Annual Report, vol. 41, part 5, 1932. 65 pages, tables, 16.5 × 24.5 cms. Toronto, King's Printer, 1933.

International Hydrographic Bureau, Year Book, 148 pages, 13.5 × 18 cms. Monaca, 1933.

National Advisory Committee for Aeronautics, Technical Notes, No. 442, Jet Propulsion with Special Reference to Thrust Augmentors, by G. B. Schubauer, 37 pages, figures, 20 × 26 cms. Washington, Committee, 1933. No. 445, Wind-Tunnel Research Comparing Lateral Control Devices, Particularly at High Angles of Attack. VIII. Straight and Skewed Ailerons on Wings with Rounded Tips, by Fred E. Weick and Joseph A. Shortal, 13 pages, tables, diagrams, 20 × 26 cms. Washington, Committee, 1933.

CURRENT TOPICS.

Gypsum-Information of Interest.—(C. L. HADDON, *Chem. & Ind.*, **52**, 24.) Gypsum is a naturally occurring form of calcium sulfate. A plausible explanation of the formation of calcium sulfate in nature is that flowing waters containing calcium bicarbonate came to rest in an inland sea containing dissolved sulfates. This resulted in the precipitation of the slightly soluble calcium sulfate. Occasionally, when conditions were favorable, large individual crystals known as "selenite" would form. Ordinarily, very fine crystalline particles are precipitated to give a gradually deepening layer of sediment which, under the pressure and other conditions of the later geologic ages, becomes consolidated in a rock-like stratum of "gypsum." Gypsum is a dihydrate of calcium sulfate and has the formula, $CaSO_4.2H_2O$. If this inland sea happened to be very warm or contained large quantities of dissolved salts another form of calcium sulfate—the anhydrous—known as "anhydrite" was deposited.

The principal use for raw gypsum is to retard the initial set of Portland cement, to which about 2 per cent. is added. It also finds application as a fertilizer, for polishing tin plates, for mine dusting and as a cheap filler in a number of industries. The purer types of gypsum are used as a loader for paints, textiles, and paper.

When powdered gypsum is heated, the mass takes on the appearance of boiling at about 120° C. This is due to escaping water vapor with the simultaneous formation of the hemihydrate of calcium sulfate ($CaSO_4.\frac{1}{2}H_2O$) better known commercially as "Plaster of Paris." If the heating is continued, a somewhat similar phenomenon occurs again at 180° C. when the last portion of the original water is driven off and anhydrous calcium sulfate is left. This form which is relatively soluble changes into the so-called insoluble form identical with the natural anhydrite when subjected to prolonged heating above 300° C.

When Plaster of Paris of greater strength than the ordinary commerical variety is required for casting pottery moulds, or in dentistry, a different method of manufacture is used producing a plaster requiring about 15 per cent. less water for gauging. Small lumps of gypsum are calcined in a muffle oven under careful temperature control and the plaster is ground in an edge runner. This method of grinding gives a proportioning of particle size that permits closer packing and hence greater strength.

When Plaster of Paris is mixed with water, crystals of gypsum begin to form and, as they grow, interlock and cohere to give a mass having considerable strength. The purest grade of Plaster of Paris procurable requires about one hour to complete its setting. Ordinary commercial grades still contain some unaltered gypsum particles which cause the plaster to become hard in 15 minutes and set completely in 35 minutes. The setting rate of Plaster of Paris is influenced by solutions of various salts. Common salt or potassium sulfate hastens setting while borax or ammonium citrate retard it to a matter of hours.

Borax, which was originally used as a retarder, is not wholly satisfactory since it gradually works its way to the surface of the plaster and forms a white powdery bloom. The retarder now generally used is made by hydrolyzing keratin with lime and caustic soda. An addition of only about 1/4 per cent. is necessary.

Dead-burned gypsum is not more soluble than gypsum itself and its setting time is too slow to be of commercial value. Therefore, it is necessary to add substances which will accelerate the setting. The original plaster of this type was known as Keene's cement and was prepared by first baking the gypsum, soaking in an alum solution, re-baking and grinding. Keene's cement sets like Portland cement and Plaster of Paris in that the mass gradually hardens at an equal rate throughout. Retarded Plasters of Paris behave differently by remaining quite soft then suddenly becoming hard at certain spots which finally extend throughout the mass.

Gypsum plasters are much more satisfactory for plastering walls and ceilings than the old-time lime and sand mixture. The advantages of using gypsum are obvious. Lime plasters set very slowly depending upon the rate of evaporation of the moisture and until such moisture escapes no decorations can be applied to the walls. In addition, while gypsum plasters are neutral, lime plasters are alkaline and are prone to damage such paints having a linseed oil base. A very satisfactory calcium sulfate plaster is that composed of a retarded Plaster of Paris where the retarder is an organic colloid.

Plaster of Paris is also a constituent of certain wall boards. One well-known variety is made by mixing up Plaster of Paris, sawdust and retarder with water, running the mixture onto one sheet of paper resting on a conveyor belt, and placing another sheet of paper on top. After the mass passes through two pressure rolls, it is cut into boards of normal size and dried out in a tunnel dryer.

The mechanical strength of gypsum plasters depends largely on the thickness of the mix. A very thick mix of Keene's cement may reach a tensile strength of 1500 lbs. per sq. in. while a thin mix may be only 500 lb. When gypsum plasters dry out they become about twice as strong as when still wet. The so-called "fatigue" which affects steel rather seriously scarcely affects gypsum plaster at all. It has been proved that gypsum plasters gauged with three parts of sand will withstand five-sixths of their breaking load four months without fracture.

C.

THE FRANKLIN INSTITUTE

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